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LABORATORY CULTURE OF JACKSMELT, *ATHERINOPSIS CALIFORNIENSIS*, AND TOPSMELT, *ATHERINOPS AFFINIS* (PISCES: ATHERINIDAE), WITH A DESCRIPTION OF LARVAE [1]

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Embryonic and larval jacksmelt, *Atherinopsis californiensis,* and topsmelt, *Atherinops affinis,* were cultured in the laboratory. Larval *A. californiensis* were grown for 24 days at 10, 20 and 30 °/oo salinity. Survival, 80–91%, was highest at 10 °/oo salinity. Increases in standard length (SL) and wet weight were greatest for larvae cultured at 10 or 20 °/oo.

Survival of larval *A. affinis* cultured at 10, 20 and 30 °/oo for 24 days ranged from 99–100%. Increases in SL and wet weight were greatest for larvae cultured at 20 or 30 °/oo salinity.

Illustrations of day of hatch, 8-, and 24-day-old larvae are presented with morphometric descriptions for each species. Unique melanophore patterns provide a useful character for identification of these two closely related atherinid fishes which occur sympatrically in California bays and estuaries.

INTRODUCTION

The jacksmelt, *Atherinopsis californiensis,* occurs from Santa Maria, Baja California, to Yaquina Bay, Oregon (Miller and Lea 1972). Jacksmelt spawn during October–March with peak reproductive activity in January–March (Allen et al. 1983).

The topsmelt, *Atherinops affinis,* has a reported range from the Gulf of California to near Sooke Harbor, Vancouver Island, British Columbia (Miller and Lea 1972). In California, individuals spawn from May–August.

The biomass and numerical abundance of these fishes has been documented for California bays and lagoons (Allen and Horn 1975, Horn 1980, Allen 1982, Allen et al. 1983). Moreover, Carpelan (1955, 1961) examined the salinity tolerance of *A. affinis* in hypersaline lagoons and Middaugh et al. (1988) oserved that juvenile *A. affinis* were euryhaline in a laboratory study.

Several reports have provided general information on culturing *A. affinis* in the laboratory (McHugh and Walker 1948, Ehrlich et al. 1979). A description of *A. californiensis* and *A. affinis* larvae from field collected material was reportedby Wang (1981).

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However, no data are available on survival and growth of larval *A. californiensis* and *A. affinis* at different salinities, using a defined culture procedure. Moreover, descriptions of larvae collected from the field did not reveal age specific characters.

The purposes of this study was to culture each species in the laboratory and provide data on survival and growth at several salinities. We also provide a description and illustration of day-of-hatch, 8- and 24-day old larvae for use in identification of field collected young.

MATERIALS AND METHODS

Larval Culture

Larval *Atherinopsis californiensis* were cultured from naturally spawned eggs collected on 15 April 1986 from Tomales Bay (lat 38° 12'N, long 123° 55'W). Eggs were identified on the basis of a description provided by White et al. (1984). Fine-tipped scissors were used to cut ~400 viable stage 20 embryos (expansion of midbrain, Lagler et al. 1977) from the ~90% nonviable embryos in the naturally spawned string-like mass.

Thereafter, embryos were maintained in a 4 L glass beaker containing 3 L of 22 ± 1° C, 30‰ salinity seawater. An airstone provided moderate agitation and gently circulated the demersal embryos into the water column. Hatching occurred after 9 days of laboratory incubation.

On the day of hatching, groups of 90 larvae were acclimated to seawater at 10, 20 or 30‰ salinity. The acclimation period was 4 hrs for larvae transferred to 20‰ and 8 hrs for 10‰, with salinity lowered 2 to 2.5‰/hr. Thereafter, 90 acclimated larvae were maintained in 18 L aquaria at the respective salinities. Salinity dilutions were made with deionized water. A 4 mm I.D. fire-polished glass tube equipped with a rubber bulb was used to transfer larvae between tanks.

On the day after hatching and daily thereafter, 90,000 newly hatched (12-hr-old) *Artemia* nauplii (5,000/L) were added to each aquarium. Twenty percent of the volume of each aquarium was replaced every other day with temperature and salinity adjusted seawater.

On the day of hatching (DOH) and days 8 and 16 after hatching, 6 larvae from each aquarium were fixed in 4% buffered formalin for subsequent measurement of standard length (SL) and wet weight. All survivors were fixed on day 24 posthatch and measured. Daily mortality was monitored prior to water changes or feeding. The photoperiod for developing embryos and larval growth was 14L:10D with an intensity of ~20 $\mu E/s/m^2$ from "cool white" fluorescent lamps.

On three occasions (June–August), we collected sexually mature *Atherinops affinis* from Estero Americano, a tributary of Bodega Bay, California (lat 38° 18'N, long 123° 00'W), using a 70 m x 2 m seine with 5 mm mesh. Water temperature ranged from 18 to 20° C and salinity was 32 to 34‰. Hydrated eggs from two females were stripped into a 20 cm glass culture dish containing 4 cm deep 30‰ seawater at 20.5° C, and fertilized by stripping sperm into the dish. After 15 minutes, eggs were washed three times with ambient seawater. The fertilized eggs, which have chorionic filaments and bind together into long strands, were wrapped diagonally around stainless steel screens, each 12 cm × 3 cm × 8 mm mesh, to form a helical-like configuration of ~700 embryos that

was never more than 3 embryos thick. Each screen was placed in a separate 500 ml light-tight plastic vacuum bottle filled with 30‰ seawater at 20.5° C, sealed and returned to Bodega Marine Laboratory (BML).

In one instance, newly fertilized embryos in plastic vacuum bottles were aerated for 30 seconds with pure oxygen. The bottles were then resealed at 19° C and 34‰ and shipped via air-express (transit time 28 hrs) to the Gulf Breeze Laboratory (GBL) in Florida.

Upon arrival at GBL, stage 18 embryos (4 to 14 pairs of somites, Lagler et al. 1977) attached to the screen were suspended in a 4 L glass beaker containing 3 L of seawater at 21 ± 1° C and 30‰. An airstone provided moderate aeration. Larval *A. affinis* were cultured at GBL in a manner identical to that described above for *A. californiensis*.

Larval Descriptions

Drawings of day-of-hatch, 8-, and 24-day-old *A. californiensis* and *A. affinis* were prepared and melanophore patterns described. Measurements of representative samples of each species and age were taken. All measurements were made under a dissecting microscope (8–32x) with digital calipers to nearest 0.1 mm. Measurement of standard length (SL), preanal distance, head length, head depth, body depth, and counts of fin rays followed the procedures of Hubbs and Lagler (1958).

Statistical Analysis

A one way analysis of variance (ANOVA) and post-hoc Student Newman-Keuls test, if appropriate, were performed on arc-sine transformed data for each age group (8-, 16-, and 24-day-old) of the respective species to determine if significant differences ($\alpha = 0.05$) in SL or wet weight existed for larvae cultured at 10, 20, or 30‰ salinity (SAS 1985).

RESULTS

Larval Culture

Newly hatched larval *Atherinopsis californiensis* possessed a yolk sac and did not begin to consume *Artemia* nauplii until yolk-sac absorption, 48 h after hatching, when they fed actively at the air-water interface. Most mortalities occurred during the first week after hatching; thereafter, a survival plateau at each culture salinity occurred through day 24. The highest survival was 91% at 10‰, while survival at 20 and 30‰ was 81 and 83%, respectively.

Growth of *A. californiensis* was rapid at the three salinities tested (Table 1). Larvae cultured at 10 and 20‰ salinity were generally longer and heavier than individuals cultured at 30‰. There was no significant difference ($\alpha = 0.05$) in the mean SL of 8- and 16-day-old larvae reared at the three salinities (Table 2). However, there were significant differences in mean wet weights of 8-, and 24-day-old larvae and SL in 24-day-old individuals. Eight-day old larvae cultured at 30‰ weighed significantly less than individuals cultured at 10 or 20‰ salinity (Table 2). By day 24, individuals cultured at 30‰ weighed significantly less and also were shorter in SL than larvae cultured at 10‰ or 20‰ (Table 2).

TABLE 1. Summary Data for Larvae Cultured at 10, 20 and 30‰ Salinity. Reported Values are Means for Samples of 6 to 10 Larvae Taken on the Day-of-hatch (0) and 8-, 16- and 24-days After Hatching.

	Age (days)											
	0			*8*			*16*			*24*		
Salinity ‰	10	20	30	10	20	30	10	20	30	10	20	30
A. californiensis												
SL (mm)	–	–	7.58	9.95	9.78	9.30	13.00	12.78	12.68	16.25	16.35	15.13
Wet wt. (mg)	–	–	2.99	6.67	6.20	4.47	16.43	15.53	14.68	38.67	40.35	31.69
A. affinis												
SL (mm)	–	–	5.19	8.68	8.80	8.51	11.60	11.51	12.35	14.65	15.31	14.95
Wet wt. (mg)	–	–	1.06	4.90	5.10	4.80	14.37	16.10	17.53	32.07	35.70	38.17

TABLE 2. Summary Data for Growth of Larvae Cultured at 10, 20 and 30‰ Salinity and Sampled When 8-, 16- and 24-days Old. One-way Analysis of Variance (ANOVA) an SNK Procedures Were Conducted for Each Age Group. SL and Wet Weight are Presented in Decreasing Order by Salinity, from Left to Right for Each Age Group. Underscored Means are Similar ($\alpha = 0.05$), NS—No Significant Difference for Larvae Cultured at Each Salinity.

	Age (days)		
	8	*16*	*24*
A. californiensis			
SL (mm)	NS	NS	$\underline{X_{20}\ X_{10}}\ X_{30}$
Wet wt. (mg)	$\underline{X_{10}\ X_{20}}\ X_{30}$	NS	$\underline{X_{20}\ X_{10}}\ X_{30}$
A. affinis			
SL (mm)	NS	$X_{30}\underline{X_{10}\ X_{20}}$	$\underline{X_{20}\ X_{30}}\ X_{10}$
Wet wt. (mg)	NS	$\underline{X_{30}\ X_{20}}\ X_{10}$	$\underline{X_{30}\ X_{20}}\ X_{10}$

Larval *Atherinops affinis* began feeding at yolk-sac absorption, 24 to 48 h after hatching. During the 24-day growth test, survival was 100% at 10 and 20‰ salinity and 99% at 30‰. Larval *A. affinis* demonstrated no salinity-related trends in SL or wet weight after 8 days of growth (Table 1). At 16 days of age, larvae cultured at 30 ‰ were significantly longer and heavier ($\alpha = 0.05$) than those maintained at 10‰ (Table 2). At 24 days of age, larvae at 20‰ were significantly longer than those maintained at 10‰ while larvae cultured at 30‰ were significantly heavier than individuals cultured at 10‰ (Table 2).

Larval Identification

Atherinopsis californiensis. Day-of-hatch. Standard length and total length (TL) of individuals were 7.9 to 8.1 mm and 8.3 to 8.4 mm, respectively (Fig. 1). Two medium-sized melanophores were situated side by side above the eyes on top of the head, and two larger melanophores were situated longitudinally behind the former ones on the occiput and nape. Some individuals did not have melanophores elsewhere, and some had them dorsally on the tail. The yolk sac had melanophores dorsally. In the latter case, the melanophores were concentrated posteriorly. Morphometry for larval *A. californiensis* is summarized in Table 3.

Atherinops affinis. Day-of-hatch. The SL and TL of described individuals were 5.2 and 5.4 mm, respectively. Mouth was formed but was not described in the figure, because of its position (Fig. 2). Two melanophores above the eyes were the same as those in *A. californiensis,* but were not present in some larvae. There were three additional melanophores behind the pair over the eyes, but there were no melanophores on the tail. The yolk sac had melanophores

dorsally and ventrally. On the dorsal surface they were concentrated; on the ventral surface they were dispersed. Morphometry for larval *A. affinis* is summarized in Table 3.

Discrimination. Day-of-hatch. Larger size and early appearance of dorsal melanophore row in *A. californiensis,* and melanophore patch on ventral surface of yolk sac in *A. affinis.*

A. californiensis. 8-days old. The SL and TL were 9.8 to 10.9 mm and 10.5 to 11.7 mm, respectively (Fig. 1). Caudal fin rays were beginning to form. Dorsal and anal fin bases had appeared. In some individuals, dorsal and anal fin rays were being formed. Melanophores were lined dorsally from the head to the end of the tail. Two large melanophores were located side by side above the eyes. A small melanophore was anterior to the former ones, just above the anterior part of the eyes, but some individuals had two melanophores of medium size at this position. Behind the pair of large melanophores located above the eyes, a line of melanophores occurred dorsally from the occiput to the tail; members of the anterior pair were large and all others small. They were in a row except where the dorsal fin was forming. Melanophores may be lined on one or both sides of the dorsal fin. There were no melanophores ventrally. The caudal fin had 11 to 14 rays (Table 3).

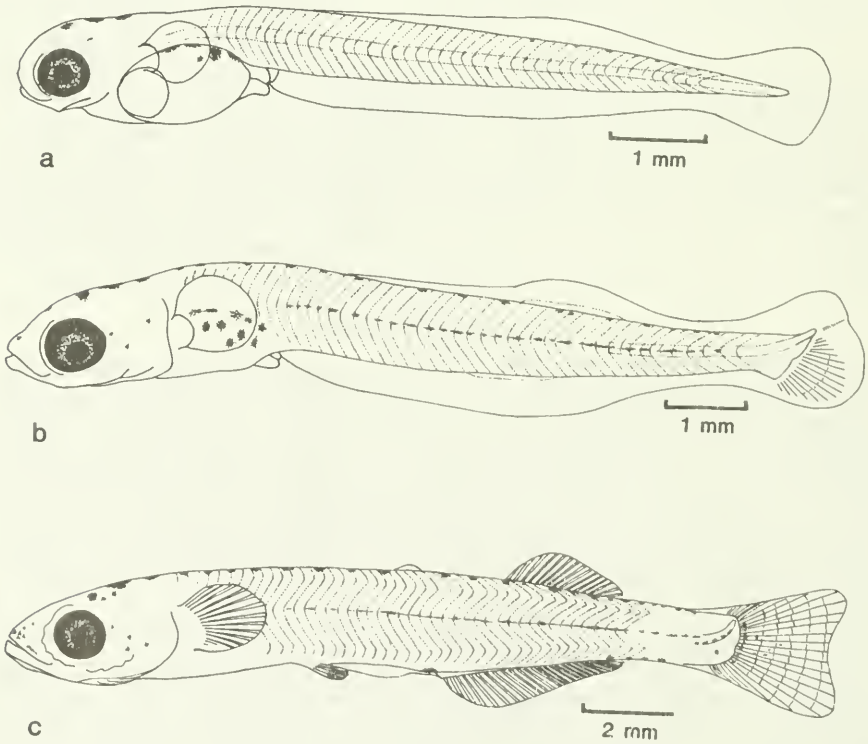

FIGURE 1. *Atherinopsis californiensis.* a. day-of-hatch, b. 8-days old, c. 24-days old.

A. affinis. 8-days old. The SL and TL were 8.4 to 9.7 mm and 9.2 to 10.1 mm, respectively (Fig. 2). Caudal fin was beginning to form. Some individuals had dorsal and anal fin bases; others did not. Two large melanophores were situated side by side above the eyes. One melanophore was located in front of the two, and behind the two, melanophores were in a longitudinal row extending close to the end of the tail. Several melanophores were on the posterior end of the notochord. Most individuals had melanophores on the base of the caudal fin. Three or four melanophores were located ventrally on the abdomen, forming a longitudinal row. A ventral row of melanophores was located on the tail, a little below the surface and inside muscle tissue. The caudal fin had 5 to 10 rays(Table 3).

Discrimination. 8-days old. Ventral melanophore row on abdomen and tail, and early appearance of melanophores along the posterior end of the notochord in *A. affinis*. Greater number of caudal fin rays in *A. californiensis*.

A. californiensis. 24-days old. The SL and TL were 15.1 to 17.6 mm and 17.6 to 20.3 mm, respectively (Fig. 1). A small fin fold remained between the pelvic and anal fins. Fins, except the first dorsal were completed or nearing completion. A large melanophore was located above each eye and two large ones were located longitudinally on the occiput and nape. Tiny melanophores

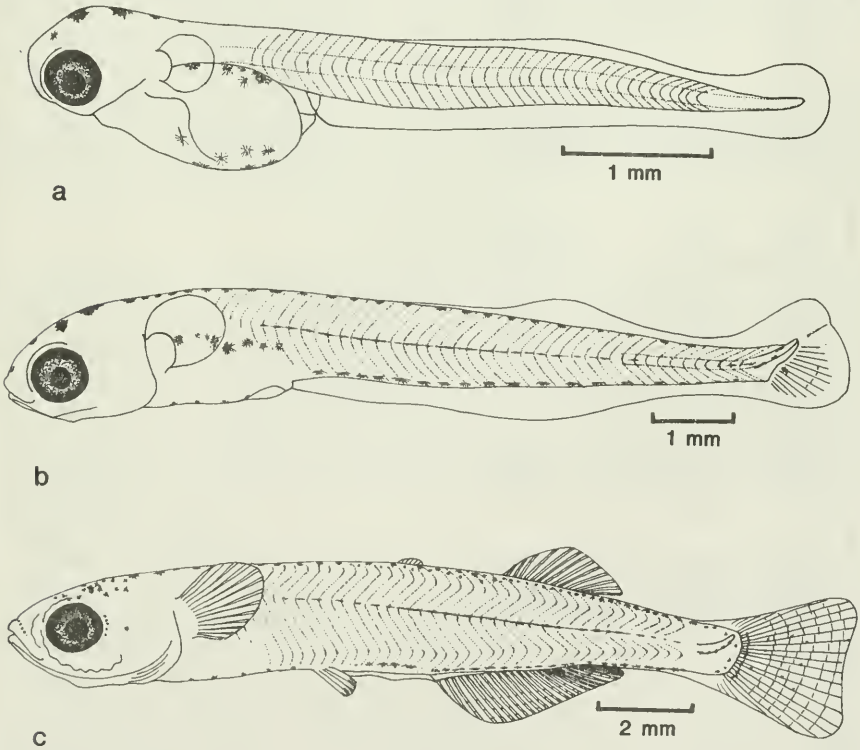

FIGURE 2. *Atherinops affinis.* a. day-of-hatch, b. 8-days old, c. 24-days old.

TABLE 3. Range of Measurements (mm) and Fin Ray Counts (means in parenthesis) for Larvae Cultured in the Laboratory. Day-of-hatch and 8-days Old (N = 5), 24-days Old (N = 19–21).

Atherinopsis californiensis	*STANDARD LENGTH*	*PREANAL DISTANCE*	*HEAD LENGTH*	*HEAD DEPTH*	*BODY DEPTH*	*1ST DORSAL*	*2ND DORSAL*	*ANAL*	*PECTORAL*	*CAUDAL*	*PELVIC*
DAY OF	7.7–8.1	–	1.1	0.9	0.7–0.8	–	–	–	–	–	–
HATCH	(7.8)	–	(1.1)	(0.9)	(0.7)	–	–	–	–	–	–
8-DAYS	9.8–10.2	–	1.6–1.8	1.1	1.1	–	–	–	–	11–14	–
OLD	(9.9)	–	(1.7)	(1.1)	(1.1)	–	–	–	–	(13)	–
24-DAYS	14.3–17.4	8.4–10.7	3.3–4.2	1.8–2.2	2.0–2.6	0	11–14	14–26	8–13	16–20	2–4
OLD	(16.0)	(9.7)	(3.7)	(2.1)	(2.2)	(0)	(13)	(20)	(10)	(18)	(3)
Atherinops affinis											
DAY OF	5.1–5.4	–	0.7–0.8	0.7	0.5		–	–	–	–	–
HATCH	(5.2)	–	(0.7)	(0.7)	(0.5)		–	–	–	–	
8-DAYS	8.6–9.1	–	1.5–1.6	1.1–1.2	1.0–1.1		–	–	–	5–10	–
OLD	(9.0)	–	(1.6)	(1.2)	(1.1)		–	–	–	(8)	–
24-DAYS	14.5–16.0	8.6–9.5	3.2–4.2	1.9–2.4	1.9–2.5	0–6	8–14	18–26	7–12	16–19	2–6
OLD	(15.0)	(9.0)	(3.5)	(2.2)	(2.3)	(3)	(12)	(23)	(9)	(19)	(4)

were scattered around the large ones and on the snout. Melanophores on the cheek were subdermal. The row of melanophores on the dorsal edge of the body was separated to both sides of the second dorsal fin. This separation was not apparent at the first dorsal fin. The lined melanophores on the lateral side were on the surface but those along the posterior end of the notochord were inside the muscle. The caudal fin bears melanophores on the basal part. No melanophores were on the anal fin base. A large melanophore, just in front of the anal fin, was conspicuous. Large melanophores bearing on the abdominal cavity wall were seen through the muscle. Fin rays were present in all but the first dorsal (Table 3).

A. affinis. 24-days old. The SL and TL were 15.1 to 16.1 and 17.5 to 18.7 mm, respectively (Fig. 2). All fins were completed. No fin fold remained. Many small and medium size melanophores were scattered around the top of the head from the snout to the nape. The row of melanophores along the dorsal edge of the body was doubled or tripled from a point slightly anterior to the first dorsal fin to the rear end of the second dorsal fin base. Several melanophores occurred longitudinally in a row from the chest to the pelvic fin. Melanophores between pelvic and anal fins formed paired longitudinal rows. Melanophores at the anal fin base and along its sides formed three longitudinal rows. However, in some individuals, melanophores along both sides were not obvious. Melanophores on the posterior end of the notochord were inside the muscle. Melanophores on the caudal fin were distributed similarly to *A. californiensis*, that is on the basal part. Rays werepresent in all fins (Table 3).

Discrimination. 24-days old. A distinct melanophore slightly anterior to the anal fin and absence of fin rays in the first dorsal of *A. californiensis*. Thicker distribution of melanophores on top of the head and back, with rows of melanophores from the chest to the rear end of the anal fin base in *A. affinis*.

DISCUSSION

Atherinopsis californiensis survival and growth was optimal at 10 and 20‰, suggesting that it may prefer mesohaline salinities (~18 ± 5‰) when young. Nearly all mortality occurred during the first 7 days posthatch; thereafter, mortality was low at each salinity for the duration of the 24-day tests. A similar trend was observed for larval inland silversides, *Menidia beryllina*, cultured at salinities of 5, 15, and 30‰, with mortality occurring during the first 6 days after hatching (Middaugh et al. 1986). They observed no additional deaths during the 16-day grow-out. The optimal salinity for survival was 15 ‰. This salinity also produced growth in SL and wet weight that was significantly greater than at 5 or 30‰.

Adult *A. californiensis* in southern California are reproductively active and reside in shallow to mid-depth (~2 to 4 m) offshore areas during the colder months, November–April (Allen et al. 1983). In warmer months, May–October, large numbers of juveniles were found in the shore zone near Cabrillo Beach. Salinities during this period ranged from 23 to 33‰ (Allen et al. 1983).

Survival of *Atherinops affinis* larvae was excellent at 10, 20 and 30‰ during the 24-day growth test. Growth showed a general trend of significantly longer and heavier 16- and 24-day-old individuals cultured at 20 and 30‰.

Recent laboratory studies of salinity tolerance in young *A. affinis* demonstrated that they are able to tolerate low salinities as well. Young fish, 24-days

old were acclimated from 10‰ to 2‰ in 2‰/day increments. All fish survived the period of acclimation to 2‰ and for 29 days at the low salinity. In a second experiment, 24-day-old *A. affinis,* initially held at 30‰, were subjected to a 2‰/day increase salinity. No mortalities occurred until 60‰ salinity. Incremental mortality occurred as salinity increased to 80‰ where the cumulative mortality was 48%. An increase to 82‰ salinity caused cumulative mortality to rise to 80% (Middaugh and Shenker 1988).

Adult *A. affinis* are reproductively active during May–August. This period generally coincides with low coastal rainfall and high salinities in California estuaries and coastal lagoons (Carpelan 1961). While we observed optimal larval growth at 20 and 30‰ and collected reproductively active adults from Estero Americano at 34‰ salinity, other field observations indicate that *A. affinis* adults may spawn at salinities up to 72‰ in the Alviso Salt Ponds of San Francisco Bay (Carpelan 1957). Moreover, Carpelan (1955) reported that waters of the Alviso Salt Ponds only became intolerable for young *A. affinis* between 80 and90‰.

Culture of larval *A. californiensis* and *A. affinis* in the laboratory enabled us to obtain individuals of known age for preparation of drawings and identification of distinguishing characteristics. Substantial differences, especially in melanophore appearance and location, were noted in individuals from each age group. These differences should be useful in identification of field-collected larvae (Figs. 1 and 2).

Where comparisons are possible, our measurements and fin ray counts are in general agreement with those provided by Wang (1981). One notable exception is the TL reported for *A. affinis* by Wang (1981) of 4.3–4.9 mm at hatching. Our day-of-hatch larvae were substantially larger, 5.1–5.4 mm, $\bar{x}$ = 5.2 mm SL.

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HARVEST DISTRIBUTION AND SURVIVAL OF MALLARDS BANDED IN CALIFORNIA, 1948–82 [1]

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Over 108,000 mallards, *Anas platyrhynchos,* were banded in the Sacramento (Gray Lodge Wildlife Area) and San Joaquin valleys (Los Banos Wildlife Area), and northeastern California (Klamath Basin, Honey Lake, Mountain Meadows) during 1948–82. Analysis of recoveries shows that adult males survived at a higher annual rate (61%) than adult females did (56%), although recovery rates of males (9%) exceeded those of females (6%). Immature mallards survived at lower rates (male 47%—female 46%) and had higher recovery rates (male 14%—female 12%) than did adults. These survival rates were nearly identical to those reported for the continent as a whole. Direct recoveries of each age/sex class of mallards banded preseason at Gray Lodge and Los Banos were obtained most frequently in the region of banding (69–84% of recoveries). This was true also for all immatures banded preseason at Klamath Basin and Honey Lake (68–78% of direct recoveries), and adult females at Honey Lake (73% of recoveries). However, most adult males, and many adult females (Klamath Basin only), migrated prior to opening of the hunting season and were recovered in areas to the south (58–64% of recoveries in Central Valley-Bay Delta); these birds were either local or other postbreeders. or molt migrants returning to the Central Valley. Several lines of evidence suggest that, during the past 35 years, a progressively larger proportion of the California mallard harvest has come from Klamath Basin and Central Valley mallard populations. First, indirect recoveries in California of Klamath Basin preseason-banded mallards increased proportionately from the 1950's to the 1980's; and, most of this increase was in the Klamath Basin (1950's—21.3% vs. 1980's—41.7% of recoveries). Concurrently, indirect recoveries of Klamath Basin banded birds declined proportionately from Canada, the Sacramento Valley, and the San Joaquin Valley. Second, the proportion of indirect recoveries of Gray Lodge preaseason-banded mallards increased in all California areas, but declined in all non-California recovery areas including Canada (7.8% in the 1950's, 1.5% in the 1970's). Also, recoveries in California of mallards banded postseason at Gray Lodge increased proportionately in the 1980's (88.4%) compared to the 1950's (62.2%); concurrently, a proportionate downward trend in out-of-state recoveries occurred, especially from Alberta (1950's—13.4% to 1980's—1.9%). This increased proportion of resident mallards, concurrent with an apparent increase in the California breeding population, coincided with a marked increase of wintering mallards in the Columbia Basin of Washington and Oregon, and a reduced breeding population in prairie Canada. Thus, mallards could be managed separately in California during periods when significant numbers of northern mallards are not present. Additional research is recommended.

INTRODUCTION

Historically, the greatest density of breeding mallards, *Anas platyrhynchos,* in North America occurred in the prairie-parklands of Alberta, Saskatchewan, and Manitoba (Bellrose 1980). However, the estimated proportion of all North American mallards which nest there has declined from 54% in 1955–64 (Crissey 1969), to 40% or less in 1979–85 (Reynolds 1987). The continental

[1] Accepted for publication October 1989.
[2] Deceased

mallard breeding population (surveyed areas only) declined from 14.4 million in 1958 (Pospahala et al. 1974) to approximately 5.5 million in 1985 (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1985), but in California, the mallard breeding population index increased from 35,950 (1962–73) to 47,800 (1974–85) over this time. Seventy-five percent of these breeders were recorded in the Sacramento Valley (Pacific Flyway Waterfowl Reports, U.S. Fish and Wildlife Service, Portland, Oregon). Also, the mallard wintering population has not shown a marked decline in the Pacific Flyway, although numbers wintering in California have declined since the early 1960's. The 1985 mid-winter survey in the Pacific Flyway estimated 1,648,700 mallards compared to the 1955–85 average of 1,757,800 (Pacific Flyway Waterfowl Report, U.S. Fish and Wildlife Service, Portland, Oregon, November 1985).

The ratio of immatures to adults in the harvest of mallards in California invariably exceeds the mean for the Pacific Flyway (U.S. Fish and Wildlife Service, Office of Migratory Bird Management, Administrative Reports July 1968–85) suggesting high recruitment rates. Thus, if survival rates of mallards in California are higher than those calculated on a continental basis (Anderson 1975), coupled with high recruitment, an increased breeding population could result. Conversely, major changes in the winter distribution of mallards within the Pacific Flyway states could explain the decrease in the number of wintering mallards found in California now, compared with 25 years ago.

In the California harvest, mallards rank second or third behind northern pintails, *Anas acuta,* and green-winged teal, *A. crecca,* and mallards are now the number one species in the harvest at most California public hunting areas (Gilmer et al. 1989). Therefore, it is critical that information be made available to better manage this important species.

My objectives in this study were to document distribution of the harvest and to calculate survival rates of mallards banded in northeastern California and in the Central Valley. This information is used to recommend research and management programs to benefit mallards in California and the Pacific Flyway.

METHODS

I was assisted in banding mallards by biologists assigned to the Waterfowl Studies Project, California Department of Fish and Game (CDFG). We banded a total of 108,165 mallards (pre- and postseason combined) in California from 1948 through 1982 (Table 1). CDFG and the U.S. Fish and Wildlife Service (FWS) cooperated in the banding on Klamath Basin National Wildlife Refuges (NWRs). Mallards were caught in baited swim-in traps, banded with standard FWS aluminum leg bands, and then released.

TABLE 1. Mallards Banded Pre- and Postseason in California, 1948–82[1].

BANDING STATION	YEARS BANDED	Males		Females		TOTAL
		Adult	Immature	Adult	Immature	
Preseason:						
Klamath Basin NWRs	1948–80	21,813	11,880	11,073	6,498	51,264
Honey Lake WA	1950–58	1,594	2,888	794	2,314	7,590
Mountain Meadows	1954–56	718	859	689	666	2,932
Gray Lodge WA	1948–81	2,474	6,664	2,271	3,798	15,207
Los Banos	1948–63	1,126	4,145	950	2,705	8,926
TOTAL		27,725	26,436	15,777	15,981	85,919
Postseason:						
Gray Lodge WA	1950–82	12,935		8,244		21,179
Los Banos WA	1953–59	646		421		1,067
TOTAL		13,581		8,665		22,246
GRAND TOTAL						108,165

[1] Does not include 806 mallards banded in the Suisun Marsh 1951–55

In the 1950's and 1960's, we banded mallards at many sites in California but in some locations we worked for only a few years or few birds were banded. For example, only 800 mallards were banded during the 1951–55 bandings in Suisun Marsh, so results are not included in this report. After the 1950's we banded only at the Klamath Basin NWRs (northeast California) and at Gray Lodge Wildlife Area (Sacramento Valley). Data from the following banding stations were used in our analysis: (i) Klamath Basin NWRs in northeastern California—key production, migration, and wintering areas; (ii) Honey Lake Wildlife Area in northeastern California 240 km south of the Klamath Basin—a nesting and migration area; (iii) Mountain Meadows in northeastern California 48 km west of Honey Lake—a minor migration and nesting area; (iv) Gray Lodge Wildlife Area in the Sacramento Valley—the major mallard wintering area in California; and (v) Los Banos Wildlife Area in the Grasslands of the San Joaquin Valley—an important wintering area.

The proportion of mallards banded each month Preseason (Table 2) and postseason (Table 3) was not constant through the years. At Klamath Basin in the 1940's and 1950's, we banded the largest share of birds in August. From the 1960's on, we concentrated preseason banding in September. At Gray Lodge in the 1950's and in 1968 (the only year of banding in the 1960's), we completed the majority of preseason banding in September and October, but shifted to August and September in the 1970's and 1980's. The largest proportion of postseason banding at Gray Lodge was accomplished in January in the 1950's and 1960's, but we shifted our work to February in the 1970's and 1980's when hunting seasons lengthened requiring more time to reach banding quotas.

TABLE 2. The Proportion of Mallards Banded Preseason at Klamath Basin National Wildlife Refuges and at Gray Lodge Wildlife Area by Month and Decade, 1950–81.

Location	Decade	N(years)	July	August	September	October
Klamath Basin	1950's	10	tr.	72.4	23.3	4.3
	1960's	10	–	17.5	82.5	–
	1970's	10	–	–	100.0	–
	1980's	1	–	–	100.00	–
Gray Lodge WA	1950's	10	0.5	9.5	38.9	51.1
	1960's	1	–	–	88.7	11.3
	1970's	10	11.1	34.7	39.7	14.5
	1980's	2	–	100.0	–	–

TABLE 3. Proportion of Mallards Banded Postseason at Gray Lodge Wildlife Area by Month and Decade, 1950–82.

Decade	*N(years)*	*January*	*February*	*March*
1950's	8	88.3	11.6	0.1
1960's	10	74.9	15.5	9.6
1970's	10	42.4	50.1	7.5
1980's	3	26.3	73.7	–

I divided California into eight band recovery areas (Figure 1), and used both direct and indirect band recoveries obtained through August 1984 for analysis. Direct recoveries are banded birds recovered during the first hunting season after banding (Anderson 1975). Indirect recoveries are bands recovered one or more years following the year of banding. Thus, indirect band recoveries occurred at any point between breeding and wintering grounds. For harvest distribution, I only used bands recovered from birds shot during the hunting season. All percentages are expressed as proportions of total recoveries of a particular banded sample. To compute survival rates, I used only bands recovered from birds shot or found dead during the hunting season.

I chose the FORTRAN computer programs ESTIMATE for postseason bandings (adults) and BROWNIE for preseason bandings (adult and young) to estimate survival and recovery rates in 28 mallard data sets from four (not Mountain Meadows) banding stations (Brownie et al. 1978). A general Chi-square test was used to test for differences in survival and recovery rates between different time periods and between different banding sites (Sauer and Williams 1989). Survival rate is the probability that a bird will live for a year following the approximate midpoint of the banding period. Recovery rate is the probability that a banded bird alive during a particular banding period will be legally shot or found dead during the subsequent hunting season and reported to the FWS Bird Banding Laboratory. I assumed that band reporting rates did not change during the study period.

RESULTS AND DISCUSSION

Distribution of the Harvest

Northeastern California

Klamath Basin NWRs. Few mallards banded preseason in the Klamath Basin moved northward; more than 90% of direct recoveries were from California (Table 4). Harvest areas within California were similar for each age/sex class, but migration to these areas did not occur at the same time. For example, direct band recoveries in northeastern California were comparatively few for adult males (32.1%) relative to recoveries of adult females (49.7%), immature males (69.7%), and immature females (71.3%). Thus, most adult males, and even many adult females (compared to immatures), migrated prior to opening of hunting season, most to the Sacramento Valley, or were less vulnerable to hunting (Table 4). The adults could have been local or other post-breeders, but more likely, these were birds that returned to the Central Valley before the hunting season after migrating to the northeast to molt after nesting, or attempting to nest, in the south (M.R. McLandress and G.S. Yarris, unpubl. data).

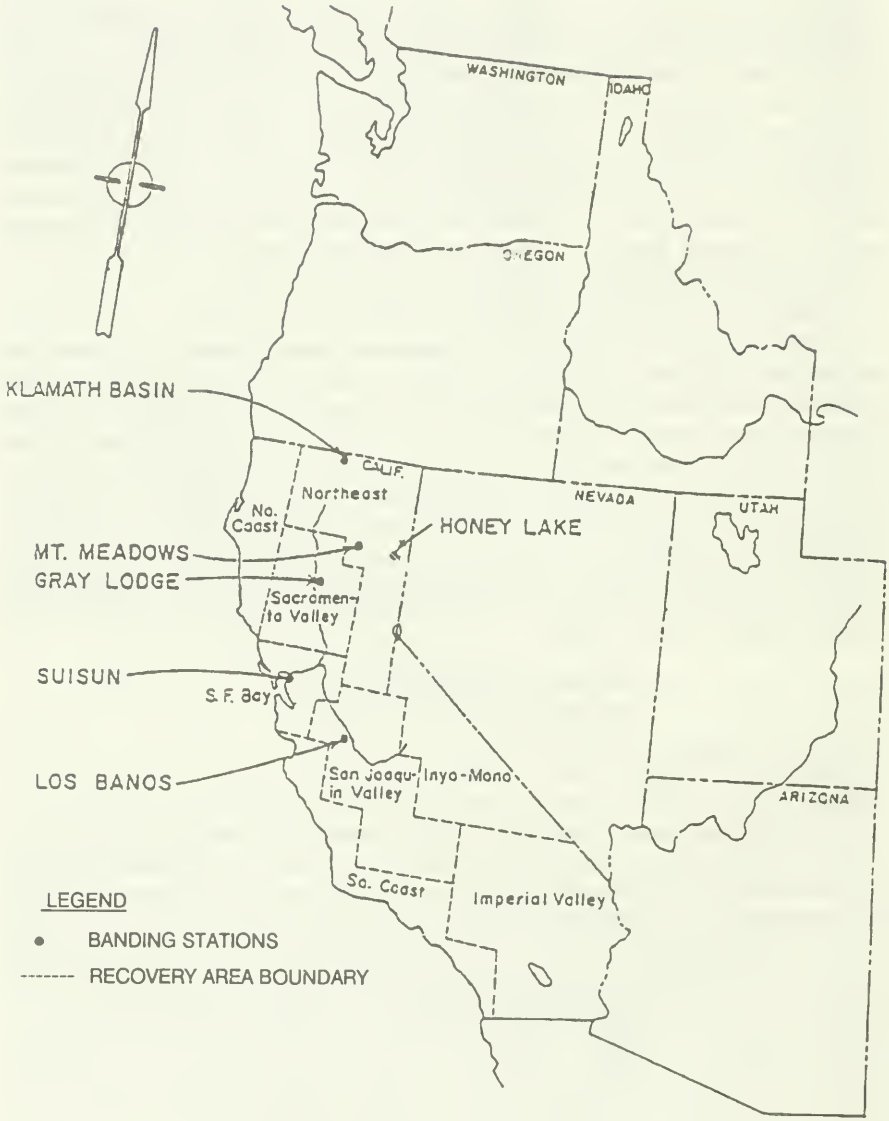

FIGURE 1. Mallard banding stations and recovery areas.

TABLE 4. Distribution of Band Recoveries (percent of recoveries) from Mallards Banded Preseason at Klamath Basin NWRs, 1948–80.

	Direct				*Indirect* [2]	
Recovery Area [1]	*Adult male*	*Imm. male*	*Adult female*	*Imm. female*	*Males*	*Females*
California						
Northeast	32.1	69.7	49.7	71.3	20.0	37.3
Sacramento Valley	41.8	17.7	30.2	16.3	44.7	33.3
San Francisco Bay-Delta	12.0	3.9	8.9	3.8	11.7	10.2
San Joaquin Valley	10.5	2.8	7.7	2.8	9.7	7.7
Washington	0.1	0.1	–	–	1.9	1.5
Oregon	1.6	4.9	1.8	4.1	4.5	6.1
Idaho	0.2	–	0.1	–	1.4	0.4
Canada	–	–	–	–	3.6	1.0
All Other [3]	1.7	0.9	1.6	1.7	2.5	2.5
Total Recoveries	1,815	1,474	665	607	3,588	913

[1] Table includes data for recovery percentage > 1.0 only. Complete list available from author.

[2] Birds in their second year or older.

[3] Recovery areas with < 1.0.

Indirect recoveries of males (87.4%) and females (89.7%) verify that California is the major wintering area for Klamath Basin preseason banded mallards (Table 4), and suggest that many were California residents. Indirect recoveries in the Sacramento Valley, San Joaquin Valley, and San Francisco Bay-Delta for males and females banded preseason in the Klamath Basin were in proportions similar to those of direct recoveries (adults). The remaining 9% of mallards recovered north of California occurred over a wider area, and may indicate breeding dispersal and northward molt migration (Martin and Carney 1977; Bellrose and Crompton 1970). Therefore, I assume that more males than the 3.6% recovered in Canada were there during the breeding season, or arrived as postbreeders to molt. Females with young generally remain on the breeding grounds until after the start of the hunting season, but some, especially failed nesters, may move north with drakes following breeding (Gilmer et al. 1977); recent evidence indicates this northern movement of adults may be more extensive in California (G.S. Yarris, pers comm.). Thus, the 1.0% females recovered in Canada may indicate females that are either dispersing to breed or migrating north to molt in Canada.

During summer 1957 on Lower Klamath NWR, we banded 461 flightless young (locals) and then, several weeks later, 486 immature mallards (Table 5). More locals (91.4%) than immatures (79.6%) were recovered in the Klamath Basin. This suggests that while many immatures were produced in the Klamath Basin, some may have come from other nesting grounds and that locals were more vulnerable at or near natal marshes.

TABLE 5. A Comparison of Direct Band Recoveries (percent of recoveries) Between 461 Flightless Young and 486 Immature Mallards Banded During Summer on Lower Klamath National Wildlife Refuge, 1957.

Recovery area	*Flightless young*	*Immature*
California		
Klamath Basin	91.4	79.6
North Coast	–	1.1
Sacramento Valley	3.7	10.2
San Francisco Bay-Delta	1.2	2.3
San Joaquin Valley	1.2	3.4
Oregon	2.5	3.4
Total Recoveries	81	88
Recovery Rate	17.6	18.1

Honey Lake Wildlife Area. The distribution of direct recoveries of Honey Lake preseason banded mallards was similar to that from the Klamath Basin including few recoveries north of California (Table 6). Proportions of each sex/age class recovered in each area were similar between the two areas, except that Nevada was more important as a minor recovery area than for birds banded in the Klamath Basin. Adult males were recovered in lower proportions in the northeast than were other sex/age classes; the Sacramento Valley was most important to adult males. But, recoveries of adult females were more closely associated with the northeast than were those of Klamath Basin banded adult females. Also, the San Joaquin Valley was more important to Honey Lake adult males than for Klamath banded adult males.

For mallards banded preseason at Honey Lake, the proportion of indirect recoveries in the northeast was less than the proportion of direct recoveries there, but direct and indirect recoveries occurred in similar proportions in the Sacramento Valley. This suggests that molters in the northeast returned to the Central Valley before the hunting season or were less vulnerable than young early in the season. There were proportionately more indirect recoveries from northeastern California, Canada, and Nevada from birds banded at Honey Lake compared to those from Klamath Basin (Tables 4 and 6). However, fewer Honey Lake banded birds were recovered in the Sacramento Valley, the Delta and total California compared to those banded in the Klamath Basin.

TABLE 6. Distribution of Band Recoveries (percent of recoveries) From Mallards Banded Preseason at Honey Lake Wildlife Area, 1950–58.

	Direct				*Indirect* [2]	
Recovery Area [1]	*Adult male*	*Imm. male*	*Adult female*	*Imm. female*	*Males*	*Females*
California						
Northeast	34.4	67.9	72.5	77.8	25.6	43.9
Sacramento Valley	30.1	19.4	17.4	12.6	34.9	22.2
San Francisco Bay-Delta	9.8	5.4	2.9	2.6	8.0	6.1
San Joaquin Valley	18.4	2.0	4.3	3.2	11.2	6.6
Washington	–	–	–	–	1.4	2.5
Oregon	2.4	2.4	–	2.0	4.4	4.6
Idaho	0.6	–	–	–	3.9	0.5
Nevada	3.1	2.7	2.9	1.8	2.0	9.1
Alberta	–	–	–	–	6.1	3.0
All Others [3]	1.2	0.2	–	–	2.5	1.5
Total Recoveries	163	458	69	342	438	198

[1] Table includes data for recovery percentage > 1.0 only. Complete list available from author.
[2] Birds in their second year or older.
[3] Recovery areas with < 1.0.

Mountain Meadows. Fewer than 28% of direct recoveries of adult females and immatures, and only 11% of adult males occurred in the northeast (Table 7). The Sacramento Valley was the most important recovery area for Mountain Meadows mallards. The comparatively low direct recovery rate in northeastern California from mallards banded at Mountain Meadows compared to those banded in the Klamath Basin and Honey Lake, reflected earlier migration of the former because of the additional 1,000 feet in elevation. But even here, adult males (molters or local post breeders) departed earlier than the other sex/age classes. Direct recoveries indicated some Mountain Meadows mallards mixed with mallards east of the Sierra Mountains (Nevada, Imperial Valley). No such

interchange was shown for mallards banded in the Klamath Basin. Indirect recoveries show a similar northward dispersion for nesting or molt as for other northeast banded mallards.

TABLE 7. Distribution of Band Recoveries (percent of recoveries) from Mallards Banded Preseason at Mountain Meadows, 1954–56.

	Direct				Indirect [2]	
Recovery Area [1]	*Adult male*	*Imm. male*	*Adult female*	*Imm. female*	*Males*	*Females*
California						
Northeast	10.7	17.8	2.7.1	28.4	5.7	24.2
North Coast	–	–	2.1	–	–	–
Sacramento Valley	53.4	42.3	43.8	39.2	45.0	39.4
San Francisco Bay-Delta	9.3	11.1	14.5	6.7	12.7	5.2
San Joaquin Valley	22.7	26.7	8.3	21.6	15.8	14.2
Imperial Valley	1.3	0.7	–	–	–	–
Washington	–	–	–	–	1.8	3.0
Oregon	1.3	0.7	2.1	1.4	3.9	4.0
Idaho	–	–	–	–	4.4	4.0
Nevada	1.3	0.7	2.1	2.7	1.3	3.0
Alberta	–	–	–	–	6.3	2.0
Central Flyway	–	–	–	–	2.5	–
Mississippi Flyway	–	–	–	–	–	1.0
Total Recoveries	75	135	48	74	158	99

[1] Table includes data for recovery percentage > 1.0 only. Complete list available from author.
[2] Birds in their second year or older.

The Central Valley

Gray Lodge Wildlife Area. The distribution of direct recoveries of mallards banded preseason at Gray Lodge was proportionately similar for each age/sex class, unlike the pattern for birds banded in northeastern California (Table 8). Direct recoveries occurred overwhelmingly in the Sacramento Valley (77.5% for adult females to 83.7% for immature females). The San Francisco Bay-Delta and San Joaquin Valley were important secondary recovery areas for these mallards, but the northeast was unimportant.

TABLE 8. Distribution of Band Recoveries (percent of recoveries) from Mallards Banded Preseason on Gray Lodge Wildlife Area, 1948–81.

	Direct				Indirect [2]	
Recovery Area [1]	*Adult male*	*Imm. male*	*Adult female*	*Imm. female*	*Males*	*Females*
California						
Northeast	0.8	1.2	2.5	1.5	6.1	8.5
Sacramento Valley	78.8	82.5	77.5	83.7	51.0	64.5
San Francisco Bay-Delta	12.8	10.6	11.9	10.2	13.0	7.1
San Joaquin Valley	6.8	5.1	8.1	4.6	9.4	5.7
Washington	–	0.1	–	–	2.9	2.8
Oregon	–	–	–	–	4.9	3.9
Idaho	–	0.2	–	–	3.0	1.2
Nevada	–	–	–	–	1.4	2.3
Canada	0.4	0.1	–	–	6.0	2.8
All Other [3]	0.4	0.2	–	–	2.3	1.2
Total Recoveries	236	984	160	411	1,096	353

[1] Table includes data for recovery percentage > 1.0 only. Complete list available from author.
[2] Birds in their second year or older.
[3] Recovery areas with < 1.0.

The Sacramento Valley was the most important area for indirect recoveries (Table 8), but those proportions (male 51.0%—female 64.5%) were markedly lower than for direct recoveries reflecting affinities to breeding and/or molting areas farther north. The proportions of indirect recoveries in the San Francisco Bay-Delta and San Joaquin Valley were similar to those of direct recoveries. As was found for Klamath Basin indirect recoveries of males, more bands were recovered in Canada, especially Alberta, than in any other area outside of California.

Recoveries of mallards banded postseason at Gray Lodge occurred over half the time in the Sacramento Valley; other recovery areas each had fewer than 10% of recoveries (Table 9). There was a markedly more northern distribution of recovery areas of postseason banded mallards relative to preseason banded birds, indicating that there were migrants as well as resident birds among mallards captured in late winter. Proportionately more females than males were recovered in the north. Also, relatively fewer females (69.3%) than males (82.2%) were recovered in California from postseason bandings, whereas in preseason bandings, relatively more females (86.4%) than males (80.2%) were recovered there. This suggests that females were more available or vulnerable to harvest relative to males at northern areas, perhaps resulting from delayed migration of successful breeders and molters. The similarity between relative recovery distribution patterns of adult males from preseason and postseason bandings suggests that molting males returned to the Valley before the hunting season, or that males which had bred in Canada were migrating into California prior to or early in the season, an unlikely event (Munro and Kimball 1982).

TABLE 9. Distribution of Indirect Band Recoveries (percent of recoveries) From Mallards Banded Postseason at Gray Lodge Wildlife Area, 1950–82.

Recovery Areas [1]	*Male*	*Female*
California		
Northeast	8.8	9.5
Sacramento Valley	59.3	51.9
San Francisco Bay-Delta	8.1	3.5
San Joaquin Valley	5.6	4.1
Washington	2.4	5.3
Oregon	5.6	10.1
Idaho	2.2	2.7
Nevada	1.3	1.6
Canada	5.2	9.7
All Other [2]	1.5	1.6
Total Recoveries	2,421	823

[1] Table includes data for recovery percentages > 1.0 only. Complete list available from author.
[2] Recovery areas with < 1.0.

Los Banos Wildlife Area. The San Joaquin Valley was the most important direct recovery area of each sex/age class for mallards banded preseason at Los Banos Wildlife Area in the Grasslands (Table 10). The Sacramento Valley and San Francisco Bay-Delta areas were important harvest areas of Los Banos mallards, but the northeast was not.

TABLE 10. Distribution of Band Recoveries (percent of recoveries) from Mallards Banded Preseason at Los Banos Wildlife Area, 1943–63.

	Direct				*Indirect* [2]	
Recovery Area [1]	*Adult male*	*Imm. male*	*Adult female*	*Imm. female*	*Males*	*Females*
California						
Northeast	–	0.6	3.4	0.1	5.9	3.6
Sacramento Valley	9.66	16.0	13.5	11.1	24.5	13.5
San Francisco Bay-Delta	11.1	13.4	7.9	14.0	10.3	10.9
South Coast	2.2	0.5	1.1	0.7	0.4	1.0
San Joaquin Valley	76.3	69.1	74.1	73.6	43.3	62.3
Washington	–	–	–	–	1.6	1.3
Oregon	–	2.2	–	–	3.9	3.6
Idaho	–	–	–	–	2.9	1.0
Nevada	–	–	–	0.3	2.3	1.3
Alberta	–	–	–	–	3.3	0.6
All Other [3]	0.8	0.2	–	0.2	1.6	0.9
Total Recoveries	135	643	89	307	521	304

[1] Table includes data for recovery percentage > 1.0 only. Complete list available from author.
[2] Birds in their second year or older.
[3] Recovery areas with < 1.0.

The proportion of indirect recoveries in California from Los Banos preseason bandings was higher for both males (84.4%) and females (91.7%) compared to Gray Lodge (male 80.2%, female 86.4%) (Tables 8 and 10). The San Joaquin Valley was the most important area for indirect recoveries; but, proportions were markedly less than for direct recoveries, especially for males, reflecting northern (including Sacramento Valley) molting, breeding, or wintering distribution.

From postseason bandings at Los Banos, recoveries of males exceeded those of females in California (78.4% vs. 59.8%); but, delayed migration resulted in proportionately more females than males being recovered in northern areas (Table 11).

TABLE 11. Distribution of Indirect Band Recoveries (percent of recoveries) From Mallards Banded Postseason at Los Banos Wildlife Area, 1953–59.

Recovery Areas [1]	*Male*	*Female*
California		
Northeast	5.6	–
Sacramento Valley	19.8	14.6
San Francisco Bay-Delta	5.6	3.2
San Joaquin Valley	46.9	42.0
Washington	0.6	6.4
Oregon	4.3	6.4
Idaho	3.7	3.2
Nevada	3.1	6.4
Utah	0.6	3.2
Canada	7.4	13.0
Central Flyway	1.2	1.6
All Other [2]	1.2	–
Total Recoveries	162	62

[1] Table includes data for recovery percentages > 1.0 only. Complete list available from author.
[2] Recovery areas with < 1.0.

Long Term Trends in Recoveries

To determine if recovery distributions had changed over the years, I compared: (i) indirect recoveries from mallards banded preseason in the Klamath Basin during the 1950's, 1960's, 1970's, and 1980's (Table 12); (ii) indirect recoveries from mallards banded preseason at Gray Lodge during

the 1950's and 1970's (Table 13); and (iii) indirect recoveries of mallards banded postseason at Gray Lodge during the 1950's, 1960's, 1970's, and 1980's (Table 14). For the Klamath Basin, there was a marked increase in recoveries from the northeast part of California (100%) and a marked decline from the Sacramento Valley, the San Joaquin Valley, and Canada. Thus, a progressively higher percentage of northeast California's mallard harvest has come from resident populations there. This suggests a reduced exchange of birds from Canada and the Central Valley with the northeast.

TABLE 12. A Comparison of Indirect Band Recoveries (percent of recoveries) Among 4 Decades of Mallards Banded Preseason at Klamath Basin National Wildlife Refuges, 1948–80.

Recovery Areas [1]	*1950–59*	*1960–69*	*1970–79*	*1980–84*
California				
Northeast	21.3	19.8	29.4	41.7
North Coast	0.5	1.2	0.8	0.2
Sacramento Valley	43.2	44.6	38.5	32.6
San Francisco Bay-Delta	9.1	11.9	12.1	9.4
San Joaquin Valley	8.4	10.5	9.7	5.7
Washington	3.0	2.0	0.7	2.3
Oregon	4.7	3.9	5.2	4.3
Idaho	1.4	1.8	0.8	0.8
Canada	6.3	3.3	1.3	1.0
All Other [2]	2.1	0.4	1.5	2.0
Total Recoveries	1,360	967	1,422	938

[1] Table includes data for recovery percentages > 1.0 only. Complete list available from author.
[2] Recovery areas with < 1.0.

TABLE 13. A Comparison of Indirect Band Recoveries (percent of recoveries) Between 2 Decades of 14,519 Mallards Banded Preseason on Gray Lodge Wildlife Area, 1948–79.

Recovery Areas [1]	*1950–59*	*1970–79*
California		
Northeast	6.2	6.9
Sacramento Valley	51.5	57.1
San Francisco Bay-Delta	10.3	13.4
San Joaquin Valley	8.5	9.4
Washington	3.3	2.5
Oregon	5.4	3.8
Idaho	2.7	2.3
Nevada	2.1	1.2
Canada	7.8	1.5
Central Flyway	1.0	0.3
All Other [2]	1.2	1.6
Total Recoveries	792	394

[1] Table includes data for recovery percentages > 1.0 only. Complete list available from author.
[2] Recovery areas with < 1.0.

TABLE 14. A Comparison of Indirect Band Recoveries (percent of recoveries) Among 4 Decades of 21,179 Mallards Banded Postseason at Gray Lodge Wildlife Area, 1950–82.

Recovery Areas [1]	*1950–59*	*1960–69*	*1970–79*	*1980–84*
California				
Northeast	8.6	8.5	9.5	10.1
Sacramento Valley	47.2	60.5	59.6	62.3
San Francisco Bay-Delta	3.4	6.5	9.3	8.7
San Joaquin Valley	3.1	5.2	6.3	6.3
Washington	4.0	3.4	2.6	1.9
Oregon	9.5	6.7	5.8	2.4
Idaho	3.8	2.3	1.4	3.4
Nevada	1.9	0.9	1.6	0.5
Alberta	13.4	3.1	2.0	1.9
Saskatchewan	2.0	0.4	0.2	–
Central Flyway	1.5	0.8	0.2	–
All Other [2]	1.6	1.7	1.5	2.5
Total Recoveries	712	1,202	1,123	207

[1] Table includes data for recovery percentages > 1.0 only. Complete list available from author.
[2] Recovery areas with < 1.0.

For preseason bandings at Gray Lodge, the proportion of indirect recoveries increased in California from 76.6% in the 1950's to 88.1% in the 1970s. Increases were noted within all important California recovery areas. Recoveries in Canada decreased from 7.8% to 1.5% in this period, and most recovery areas outside of California had fewer recoveries in the later period. Thus, Gray Lodge preseason bandings probably contained progressively more resident mallards.

Recoveries of mallards banded postseason at Gray Lodge increased proportionately over the years in all recovery areas of California; the sharpest increase occurred between the 1950's and the 1960's. The proportion of out-of-state recoveries declined in all areas, but especially in Alberta (13.4% in the 1950s, $<2\%$ in the 1980s). These results suggest that postseason banding samples have contained fewer and fewer migrants. Interestingly, the apparent sharp decrease in the presence of migratory mallards in California between the 1950s and the 1960s corresponded to the concurrent increase in mallards overwintering in the Columbia Basin of Washington and Oregon (Pacific Flyway Waterfowl Reports, U.S. Fish and Wildlife Service, Portland, Oregon).

The data on changes in recovery distributions must be interpreted with caution. The results seem to show that fewer northern mallards migrate to California compared with 30 to 40 years ago. However, similar changes in recovery distributions could have resulted from changes in hunting pressure or in migration chronology (Jim Nichols, U.S. Fish and Wildlife Service, pers. comm.), though such changes have not been documented. Importantly, the apparent trends in recovery could have resulted from the changes in banding dates over the years (Tables 2 and 3), although the evidence is contradictory.

For example, preseason banding in the Klamath Basin occurred later in the 1960s–1980s (September) than during the 1950s (August). Theoretically, these later bandings would have included proportionately more migrants relative to resident mallards, although few migrants arrive in California this early (Munro and Kimball 1982). Consequently, I would have expected there to have been progressively more northern recoveries, but the opposite occurred, supporting the notion that fewer northern mallards are migrating to California compared to earlier years.

The Gray Lodge bandings provided evidence contrary to that of Klamath bandings. Preseason bandings occurred earlier (August vs. September) and postseason bandings occurred later (February vs. January) over the years at Gray Lodge (Tables 2 and 3). Both of these changes would be expected to result, theoretically, in a sample containing proportionately fewer migrant mallards relative to residents, and ultimately would result in a recovery distribution progressively concentrated in California. Although few if any northern mallards would be expected at Gray Lodge even as late as September (Munro and Kimball 1982), the pattern of recoveries has changed as predicted.

To determine if the change in recovery distribution resulted simply from changes in the period of banding or a real change in mallard distribution, I used shorter intervals: preseason = August, September, October; postseason = January, 1–15 February, 16–29 February, and March. I analyzed indirect recovery distributions by decade of mallards banded in each of these intervals for Gray Lodge bandings. I also analyzed the proportion of California recoveries by decade for preseason bandings in southwest and westcentral Alberta, the

province which contributes the greatest number of mallards to California (Munro and Kimball 1982).

Recoveries from postseason banded mallards at Gray Lodge during each of the shorter intervals followed the same pattern as for the entire postseason period combined. Specifically, recoveries in California ranged from 61–68% in the 1950's, 80–88% in the 1960's, 83–85% in the 1970's, and 85–100% in the 1980's; recoveries from Canada showed concurrent declines through the decades: 8–12.5%in the 1950's, 3–3.4% in the 1960's, 2.3–4.1% in the 1970's, and 0–5.9% in the 1980's depending on specific time intervals. There was no tendency for greater California (fewer Canadian) recoveries for later bandings (e.g., March vs. January). Likewise, distribution of preseason banded mallards for each of the short time intervals followed the pattern of more California (85.71–91.52% vs. 77.19–81.14%) and fewer Canadian (0.61–1.76% vs. 5.93–8.77%) recoveries between the 1970's and 1950's respectively, as shown by the combined preseason bandings. For mallards banded in Alberta, using all recoveries, more occurred in California in the 1950's (4.76%) than during the other decades (2.14–3.21%). Thus, these data suggest strongly that the documented changes in recovery distributions reflect real changes in mallard distributions, and are not artifacts of time of banding, and that the greatest change occurred from the 1950's to the 1960's coincident with the increase in wintering mallards in the Columbia Basin.

Potential Migration Routes

The late migration of females and the resulting recoveries from out-of-state are an asset in delineating breeding and migration staging areas that are important to mallards harvested in California. Anderson and Henny (1972) reported that the only out-of-state mallards banded preseason that contributed significantly to the harvest in California were those banded in eastern Oregon. Preseason mallard bandings on Malheur NWR, Oregon, 1961–71 indicated that 54.3% of the male and 57.7% of the female indirect recoveries had come from the Central Valley, especially the Sacramento Valley (Furniss 1974). The most important Pacific Flyway migration corridors extend from Alberta to the Columbia Basin (Washington and Oregon), and from Alberta to the Snake River near Boise, Idaho (Bellrose 1980). Other corridors lead to the Snake River in eastern Idaho and the Klamath Basin in northeastern California. From these wintering areas, some mallards continue on to the Central Valley of California, and a few to Mexico. Data obtained from mallards banded in California indicate that these migration routes are represented by band recoveries, but that migrant mallard populations are far less important to California's harvest than are those locally produced, especially since the 1960's.

Band Recovery And Survival Rate Estimates

Recovery rates based on preseason bandings are an index to harvest rates (Anderson and Burnham 1976, Henny and Burnham 1976). The average estimated recovery rate for California banded adult male mallards was 9%. This compares with 6% for adult females, 14% for immature males, and 12% for immature females (Table 15). Thus, both adult and immature males faced greater hunting pressure than females did, but females suffered greater non-hunting mortality (Anderson and Burnham 1976). Similar results have been

reported for American wigeon, *Anas americana,* (Rienecker 1976), northern pintail (Rienecker 1987), and continental mallards (Anderson 1975). High nonhunting mortality of hens results from predation during nesting (Cowardin et al. 1985).

TABLE 15. Average Annual Recovery Rate Estimates for Mallards Banded in California, 1948–81. Standard Errors in Parentheses.

		Males			Females	
Data set	*Model* [a]	*Adults*	*Immatures*	*Model* [a]	*Adults*	*Immatures*
Preseason						
Klamath Basin						
1949–64	H1	0.071 (0.0022)	0.130 (0.0055)	H2	0.033 (0.0058) [b]	0.086 (0.0065)
1965–80	H1	0.083 (0.0023)	0.118 (0.0054)	H02	0.054 (0.0024)	0.107 (0.0084)
Honey Lake						
1950–58	H1	0.082 (0.0072)	0.153 (0.0074)	H1	0.095 (0.0106)	0.133 (0.0075)
Gray Lodge						
1948–58	H02	0.082 (0.0091)	0.126 (0.0116)	–	– [c]	– [c]
1972–81	H02	0.103 (0.0082)	0.144 (0.0100)	H2	0.034 (0.0089) [a]	0.114 (0.0101)
Grasslands						
1951–59	H02	0.102 (0.0079)	0.137 (0.0075)	H02	0.081 (0.0085)	0.118 (0.0097)
Postseason						
Gray Lodge						
1954–68	M1	0.057 (0.0021)	–	M3	0.038 (0.0022)	–
1971–81	M1	0.086 (0.0053)	–	M2	0.040 (0.0032)	–

[a] Brownie et al. (1978).
[b] After first-year adult recovery rates, f_i of Brownie et al. (1985), are presented.
[c] Insufficient data to calculate estimates.

Estimated average survival rates for all California banded mallards were 61% for adult males, 56% for adult females, 47% for immature males, and 46% for immature females (Table 16). These rates are nearly indistinguishable from continental values 1961–70 (Anderson 1975), so survival alone cannot account for an increasing breeding population in California. There was evidence of variation in average survival rates among the four different banding locations (Table 17). Anderson (1975) concluded that there were regional differences in survival estimates of North American mallards.

TABLE 16. Average Annual Survival Rate Estimates for Mallards Banded in California, 1948–81. Standard Errors in Parentheses.

		Males			Females	
Data set	*Model* [a]	*Adults*	*Immatures*	*Model*	*Adults*	*Immatures*
Preseason						
Klamath Basin						
1949–64	H1	0.62 (0.012)	0.41 (0.026)	H2	0.53 (0.048)	0.49 (0.098)
1965–80	H1	0.63 (0.011)	0.54 (0.029)	H02	0.55 (0.013)	0.49 (0.044)
Honey Lake						
1950–58	H1	0.57 (0.043)	0.42 (0.045)	H1	0.62 (0.165)	0.43 (0.088)
Gray Lodge						
1948–58	H02	0.56 (0.025)	0.51 (0.064)	–	– [b]	– [b]
1972–81	H02	0.62 (0.022)	0.43 (0.043)	H2	0.58 (0.090)	0.72 (0.211)
Grasslands						
1951–59	H02	0.53 (0.019)	0.36 (0.032)	H02	0.48 (0.026)	0.46 (0.055)
Postseason						
Gray Lodge						
1954–68	M1	0.65 (0.015)	–	M3	0.57 (0.016)	–
1971–81	M1	0.63 (0.033)	–	M2	0.60 (0.026)	–

[a] Brownie et al. (1978).
[b] Insufficient data to calculate estimates.

TABLE 17. Chi-square Tests for Temporal and Geographic Variation in Mallard Survival and Recovery Rates Computed Using CONTRAST (Sauer and Williams 1989).

		Survival Rates			*Recovery Rates*		
Test	*Age-sex*	x^2	*df*	*P*	x^2	*df*	*P*
Klamath Basin 1949–64 vs. 1965–80	AM	0.4	1	0.54	14.2	1	<0.01
	AF	0.2	1	0.69	11.2	1	<0.01
	IM	11.1	1	<0.01	2.4	1	0.12
	IF	0.0	1	>0.99	3.9	1	0.05
Gray Lodge 1948–58 vs. 1972–81	AM	3.2	1	0.07	2.9	1	0.09
(Preseason)	AF	–	–	–	–	–	–
	IM	1.1	1	0.30	1.4	1	0.24
	IF	–	–	–	–	–	–
Gray Lodge 1954–68 vs. 1971–82	M	0.3	1	0.58	25.9	1	<0.01
(Postseason)	F	1.0	1	0.33	0.3	1	0.61
Klamath Basin (1965–80) vs. Gray Lodge	AM	0.2	1	0.68	5.5	1	0.02
(1972—81)	AF	0.1	1	0.74	5.2	1	0.02
	IM	4.5	1	0.03	4.7	1	0.03
	IF	1.1	1	0.29	0.3	1	0.59
Klamath Basin (1949–64) vs. Honey Lake	AM	17.9	3	<0.01	16.4	3	<0.01
(1950–58) vs. Gray Lodge (1948–58)	AF	1.4	2	0.49	37.9	2	<0.01
vs. Grasslands (1951–59)	IM	4.8	3	0.19	7.2	3	0.07
	IF	0.2	2	0.90	23.6	2	<0.01

Survival estimates based on banding waterfowl representing several subpopulations in unknown proportions is cause for caution in interpretation of results (Pollack and Raveling 1982). Not only do young waterfowl disperse rapidly after fledging, but adults often migrate north to molt following the breeding season (Gilmer et al. 1977, M.R. McLandress and G.S. Yarris, unpubl. data). Because little nesting of mallards occurs south of California, most mallards banded in California are believed to be resident birds. Therefore, survival estimates of mallards banded in California are heavily weighted towards resident birds, especially preseason banded birds, but are equivalent to continental rates in any event.

CONCLUSIONS

The declining rate of return of California banded mallards from Canada over the past several decades could have resulted from declining numbers of mallards in Canada relative to California (Cooch and Boyd 1984), or from a change in timing of migration and distribution patterns and hunting pressure. The mallard breeding population in the southern portions of Alberta, Sadkatchewan and Manitoba has declined from an average of 4.4 million during the 1970's to 3.1 million during the first four years of the 1980's (Bartonek et al. 1984, Cooch and Boyd 1984) compared to the increase in mallards breeding in California. That fewer Canadian produced mallards winter in California also may reflect "short-stopping" in the Columbia Basin of Washington State beginning in the early 1960's. This resulted from increased wetland habitat and corn production associated with the Columbia Basin irrigation project (Bureau of Reclamation) (Pacific Flyway Waterfowl Reports, U.S. Fish and Wildlife Service, Portland, Oregon). Only in years of extreme cold and snow in the Columbia Basin, do significant numbers of northern mallards migrate to California, for example 1985–86.

Recovery distributions suggest that a greater proportion of mallards banded in the northeast part of the state have become resident there, with fewer migrating to the Sacramento Valley. Population counts on Klamath Basin refuges no longer show a peak population of mallards in spring (E. H. McCollum, pers.

comm.). Apparently, mallards which used to migrate north from the Central Valley to the Basin to nest no longer do so. Thus, at least two subpopulations of California mallards are evident from banding analysis, one associated with the Central Valley and the other with the northeastern part of the state.

The California breeding population of mallards has increased, but estimates of its size may be too low. The late timing of the breeding pair survey in the Central Valley (last week in May) relative to the peak period of nesting in late March, only partial survey of California breeding areas and the lack of visibility corrections, may produce potentially serious underestimates of the breeding population (M.R. McLandress, unpubl. data). The magnitude of such an underestimate is not known.

Male mallards normally pair in winter and follow their mates to the female's natal home (Johnsgard 1958). Thus, in general, co-mingling of mallards from many breeding areas during winter makes harvest management of each breeding population difficult. Although the population wintering in California consists largely of resident mallards, which have not suffered marked declines, occasional but regular movement of large numbers of northern mallards into California caused by adverse weather conditions in the Columbia Basin, as well as the small annual influx of northern birds, suggests management should, in general, be sensitive to Pacific Flyway objectives. However, the California breeding population, which has steadily increased, in contrast to continental trends, could be managed separately during the early hunting season before significant numbers of northern mallards would be expected to arrive in California.

My results suggest that a strengthened research effort is needed to assess the complete breeding distribution and nesting density of mallards in California, identify the limiting factors to mallard production throughout this breeding range, document the locations to which fledglings disperse, completely assess the significance of mallard molt migrations in California, and examine in detail the relationship between mallards in California and the rest of the Pacific Flyway. The latter includes a concerted effort to band representative samples of mallards throughout the Flyway. Additionally, researchers need to determine the proper timing of the spring breeding pair survey in California, as well as reasons for geographic variation in survival rates within the state. Timing of banding within pre- and post-season periods should remain consistent in the future to assist interpretation of recovery distributions.

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HOMING BY CHINOOK SALMON EXPOSED TO MORPHOLINE [1]

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Juvenile chinook salmon, *Oncorhynchus tshawytscha,* of the 1977 and 1979 brood years were exposed to $5x10^{-5}$ mg/l of morpholine for 40 d and 17 d, respectively, in a hatchery, and then released into Mad River, California. An unexposed control group from each brood year was also released. During the 1979–84 spawning seasons, when treated fish were expected to return as adults, morpholine was added continuously to the water in the Mad River Hatchery fish ladder to maintain a concentration similar to $5x10^{-5}$ mg/l. Morpholine failed to increase the chinook salmon return rate to the hatchery, probably due to incomplete imprinting. Morpholine did not affect chinook salmon survival after release, ocean catch rate, or growth.

INTRODUCTION

The ability of migratory salmonids to accurately locate their natal streams has been reviewed by various authors (Hasler 1966, Harden-Jones 1968, Hasler et al. 1978, Hasler and Scholz 1983). Olfaction appears to be the principal sense used by the fish to identify freshwater home areas through the detection of distinct odors in the home stream (Hasler 1966, Harden-Jones 1968, Kleerekooper 1969, Cooper et al. 1976, Hasler and Scholz 1983). Coho salmon, *Oncorhynchus kisutch,* smolts, exposed to morpholine or phenethyl alcohol before release in Lake Michigan, homed, as adults, to streams or an area in the lake scented with the same odors (Cooper et al. 1976, Scholz et al. 1976, Johnsen and Hasler 1980). Hassler and Kucas (1988) demonstrated that coho salmon imprinted on morpholine detected and homed to morpholine after living in the ocean for several months to 2 years. The chemical and physical properties of morpholine and the criteria for its selection as an imprinting chemical are described by Scholz et al. (1975). No information is available for the use of morpholine in California. To the best of our knowledge, morpholine was not used by any other persons near Mad River during the study.

The mean number of female chinook salmon spawned at Mad River Hatchery from 1971–72, the first year of operation, through 1980–81 was 67 fish, well below the 1,500 females needed for full production (Kucas 1981). The low return of mature salmon may be due, in part, to poor homing to the hatchery fish ladder. The water in the hatchery raceways is recirculated well water with about 10% makeup from well water. At the time of this study, the water in the fish ladder was a mixture of about 90% single pass pumped river water and 10% hatchery raceway water (Kutchins 1986), which may not have adequately attracted returning fish, causing straying. Also, the mouth of the ladder is on the river bank parallel to river flow, providing poor fish access.

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The study objective was to determine if the proportion of chinook salmon, *Oncorhynchus tshawytscha,* adults returning to Mad River Hatchery could be significantly increased by exposing smolts to morpholine, and later using morpholine to attract adults to the hatchery when they returned to spawn.

METHODS

The experiments were conducted at the California Department of Fish and Game's Mad River Hatchery about 19 river km from the Pacific Ocean near Eureka, California. The 1977 and 1979 chinook salmon brood years (here termed BY77 and BY79) were used in the experiment. The fish were randomly divided into two groups, treated and control, and marked with fin clips or coded wire tags (CWT) (Table 1). Treated fish were exposed to about $5x10^{-5}$ mg/l of morpholine in a flow-through hatchery raceway for 17 d or 40 d before they were released into Mad River. The BY77 fish were released in December 1978 as yearlings and the BY79 fish were released in June 1980 as fingerlings. Control fish, held upstream in the same raceway, were not exposed to the morpholine.

TABLE 1. Description and Treatment of Chinook Salmon Used in Experiments With Morpholine at Mad River Hatchery, California.

Brood year	Days exposed	No. released and mark[a]		Date released	Size at release Fork length range (cm)
		Treated	Control		
1977	40	40,180 LV	41,800 LP	Dec1978	13–25
1979	17	18,164 CWT	18,367 CWT	June1980	8–13

[a] LV = left ventral, LP = left pectoral, CWT = coded wire tag and adipose fin clip.

When mature BY77 and BY79 chinook salmon began to return to the hatchery in September of 1979–84, morpholine was added to the water in the hatchery fish ladder as described by Hassler and Kucas (1988). The estimated landings of CWT BY79 chinook salmon in the ocean fishery were obtained from Pacific Marine Fisheries Commission, Portland, Oregon. A X^2-test was used to compare the returns to the hatchery and ocean landings of treated and control fish by brood year.

RESULTS

Of 118,511 chinook salmon released from the hatchery in the two years, only 99 (0.08%) returned to the hatchery—58 treated and 41 control (Table 2). Among the fish that returned in both experiments, the number of treated fish was not statistically different ($P > 0.05$) from that of the controls. The return rate of chinook salmon was significantly higher for BY79 (0.18%) than for BY77 (0.04%) ($P < 0.05$). Mean fork lengths FL of treated and control fish of BY79 that returned to the hatchery were similar (Table 3).

TABLE 2. Return of Experimental Chinook Salmon to the Mad River Hatchery, California (T = treated, C = control).

Brood Year	Number released	Number returned[a]					
		1979	1980	1981	1982	1983	Total
1977	40,180 T	9	9	1	–	–	19
	41,800 C	8	4	1	–	–	13
1979	18,164 T	–	–	21	18	0	39
	18,367 C	–	–	13	14	1	28

[a] Numbers of treated and control fish that returned to the hatchery were not significantly different in any year. No experimental fish returned in 1984.

The numbers of treated and control chinook salmon of BY79 landed in the ocean commercial and sport fisheries, estimated from CWT recoveries, were not statistically different ($P > 0.05$). The estimated landing was 268 fish—142 treated and 126 control (Table 3). In 1982, when 96% of the fish were landed, the length (mean and range) of treated and control fish was similar (Table 3). The landing rate of BY79 salmon was 0.73% and the return to the hatchery was 0.18%, for a landing to hatchery escapement ratio of 4:1.

TABLE 3. Return of 1979 Brood Year Experimental Chinook Salmon to Mad River Hatchery and Landed in the Ocean Fishery (T = treated, C = control).

Year	*Number*[a]	*Fork length (cm) Mean (range)*
1981	Returned	
T	21	57 (53–64)
C	13	58 (47–64)
	Landed	
T	2	49 (48–50)
C	1	41
1982	Returned	
T	18	79 (60–97)
C	14	78 (71–89)
	Landed	
T	133	70 (64–75)
C	123	69 (64–80)
1983	Returned	
T	0	
C	1	73
	Landed	
T	7	62
C	2	78
Totals	Returned 67	
	Landed 268	

[a] Numbers of treated and control fish landed in the ocean fishery or at the hatchery were not significantly different in any year. No experimental fish were landed or returned in 1984.

DISCUSSION

The failure of morpholine to increase the proportion of chinook salmon returning to Mad River Hatchery was possibly due to incomplete imprinting. The BY79 salmon were exposed to morpholine for only 17 days before they were released from the hatchery because of a change in hatchery management (fish were released in early June at age 0 instead of in October at age 1) and many salmon may not have imprinted to the chemical. In salmonids, high levels of the hormone thyroxine are associated with imprinting and smoltification (Dickhoff et al., 1978, Folmar and Dickhoff 1980, Scholz 1980). Grau et al. (1982) identified four thyroxine peaks in BY80 juvenile chinook salmon from Iron Gate Hatchery, California, and suggested that all of the fish may not have peaked simultaneously. Thus, the number of chinook salmon that imprint to morpholine may be increased by a longer exposure time. Hassler and Kucas (1988) found that coho salmon smolts were imprinted to morpholine after 41 days of exposure at Mad River Hatchery and returns of morpholine-exposed fish were 276% higher than those of control fish ($P < 0.05$). It is also possible that exposure to a higher concentration of morpholine may increase imprinting. The small sample size of adult salmon hatchery returns reduces the strength of

our finding that morpholine does not improve homing. We believe that the poor returns of BY77 fish was due to disease *(Ichthyophthirius multifilis),* late release of juveniles due to low river flows, and below average river flows for upstream migration of spawning adults. For BY79, ocean survival was probably reduced due to a severe El Niño in 1982–83 (Hayes and Henry 1985).

The numbers of treated and control BY79 chinook salmon landed in the ocean fisheries were not significantly different. These data indicate that morpholine did not affect chinook salmon survival after they were released from the hatchery or their susceptibility to being caught in the ocean. Also, the lengths of treated and control salmon landed in the ocean and returning to the hatchery were similar, indicating that morpholine did not affect fish growth.

The imprinting process in salmonids is not completely understood. It is believed that imprinting of migratory salmon occurs just before and during initial downstream migration of smolts (Ricker 1972; Hasler and Scholz 1983). However, downstream migratory behavior and saltwater tolerance differs among species and within a species. Further study is required to determine the best method and time to imprint and release chinook salmon from a hatchery. The studies should include an accurate evaluation of the smolt transformation period and include coloration, osmoregulatory capability, and salinity tolerance and preference, and migratory activity.

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MOVEMENT AND SURVIVAL OF TOURNAMENT-CAUGHT BLACK BASS AT SHASTA LAKE [1]

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Tournament-caught smallmouth, *Micropterus dolomieui,* and largemouth bass, *M. salmoides,* at Shasta Lake were tagged to evaluate displaced bass movement. Of 180 tagged smallmouth bass recaptures, more than 87% moved from 1.6 km to 30.6 km from the release sites. Smallmouth bass recaptures during the first 20 days averaged 5.8 km from the release sites. For the entire study period, the distances between release and recapture locations for smallmouth bass averaged 8.5 km.

Of 34 largemouth bass recaptures, 62% occurred from 1.6 to 17.7 km from the release sites. Largemouth bass recaptures averaged 2 km from the release sites in the first 40 days while recaptures for the entire study period averaged 3.5 km from the release sites. Annual survival rates for smallmouth and largemouth bass were estimated at 0.13 and 0.15, respectively.

INTRODUCTION

Major black bass tournament sponsors in California are required to obtain a permit for each event from the California Department of Fish and Game and release all bass alive after weighing. The permit sometimes requires sponsors to transport and release bass away from the tournament weigh-in site to ensure dispersal, because earlier studies of bass released at initial capture locations indicate that bass normally do not move great distances but tend to remain in restricted home ranges for long periods (Latta 1963, Lewis and Flickinger 1967, Miller 1975, Coble 1975). In developing permit conditions for bass tournaments, it had been assumed that bass caught at various locations on a lake and released at a common weigh-in site would establish a new home range at or near the release site. Repeated bass releases at weigh-in sites were expected to result in abnormally large bass concentrations there. To prevent bass accumulation, redistribution seemed appropriate. However, the additional handling and confinement associated with redistribution increases stress (Carmichael et al. 1984). Furthermore, movements of relocated smallmouth bass, *Micropterus dolomieui,* were much greater than for bass that were not relocated (Forney 1961, Blake 1981, Pflug and Pauley 1983), suggesting that transporting tournament-caught smallmouth bass to disperse them may be unnecessary. A tagging study was initiated at Shasta Lake in 1985 to evaluate movement and annual survival of tournament-caught smallmouth and largemouth bass, *Micropterus salmodies*, released at two marinas and to determine if bass redistribution is necessary to ensure dispersal.

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DESCRIPTION OF SHASTA LAKE

Shasta Lake is a 5,551 hm^3 impoundment formed by Shasta Dam on the Sacramento River, 11 km upstream from Redding, California (Figure 1). The dam was constructed by the U.S. Bureau of Reclamation in the early 1940s to provide water for irrigation, electrical power, and flood control. The reservoir has a surface area of 11,947 ha and 587 km of shoreline at full pool elevation (325 m). Water is stored during the winter for agricultural use mainly during the summer, which causes the water level to fluctuate greatly, with the highest levels occurring in the spring and lowest in the fall.

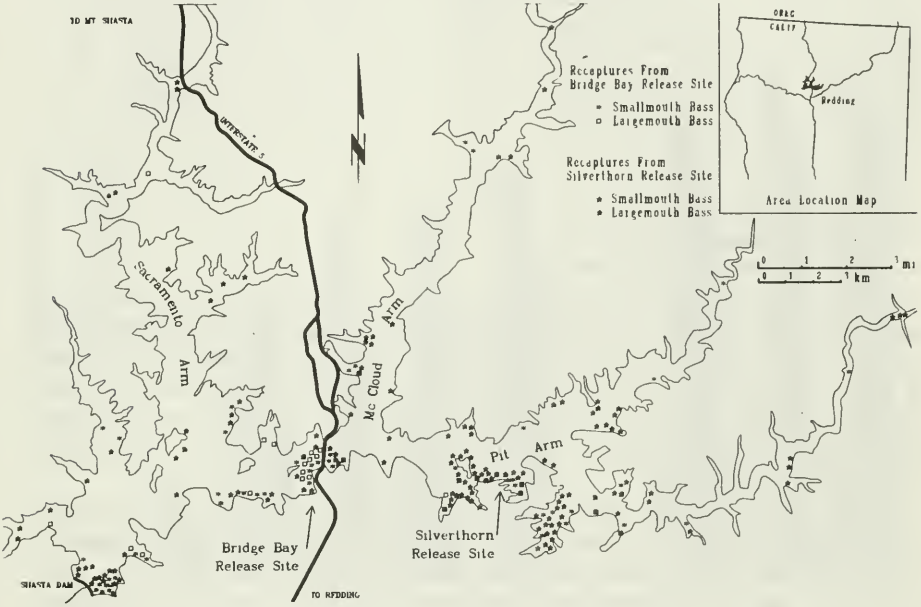

FIGURE 1. Map of Shasta Lake showing tagged bass release sites and recapture locations.

METHODS

A total of 126 tournament-caught smallmouth bass and 41 largemouth bass, from undetermined locations throughout the lake, were tagged with nonreward trailer tags and released at the Bridge Bay Marina on March 2, 1985 (Figure 1). Likewise, on 22 and 23 March, 1985, 371 smallmouth and 42 largemouth bass were tagged and released at the Silverthorn Marina (Table 1). Green vinyl plastic trailer tags, measuring 16 mm × mm × 0.8 mm and inscribed with the letters "NR" and instructions for returning the tag by mail were attached to the fish by threading soft 0.3 mm stainless steel wire through 21-gage × 3.8 cm hypodermic needles temporarily inserted through the back of the fish at the anterior base of the first dorsal fin. Following removal of the needles, the wires of the tag bridles remained in the fish and were fastened by twisting the ends and cutting off the excess wire. Trailer tags attached in this manner were found

to have high retention (Nicola and Cordone, 1969). Non-reward tags were used rather than reward tags to eliminate possible bias from anglers who might exert a disproportionate amount of fishing effort at the marina docks, compared to other areas of the lake, for the purpose of catching tagged fish for the rewards.

TABLE 1. Numbers of Shasta Lake Bass Tagged and Released in 1985 by Length Class.

	Smallmouth bass		*Largemouth bass*	
	Bridge Bay [1]	*Silverthorn* [2]	*Bridge Bay* [1]	*Silverthorn* [2]
Fork length (mm)				
280–305	10	4	1	1
306–330	80	224	6	10
331–356	22	97	17	14
357–381	10	36	10	9
382–406	2	6	4	5
407–431	1	4	1	1
432–456	1	–	1	1
457–481	–	–	1	–
482–506	–	–	–	–
507–531	–	–	–	1
Total	126	371	41	42
Mean fl (mm)	323	328	353	356

[1] Bass tagged and released on 2 March 1985.
[2] Bass tagged and released on 22–23 March 1985.

Anglers who returned tags were asked to describe capture locations and dates and mark the locations on a map. Only first time recaptures were used in the analysis. Bass movement was measured as the shortest distance from the point of release to the reported capture location on the lake. A few tags were returned without recapture location information and were not used to determine movement but were used to estimate annual survival because they were returned in the first year.

Annual survival rates were estimated from tag return ratios between succeeding years (both release sites combined) based on Ricker's formula 4.2 (Ricker 1958). Recaptures from day 0–365 were included as first year recaptures. Second and third year recaptures were from day 366–730 and day 731–1,095, respectively.

RESULTS

Bass Recaptures

Total returns of the tagged bass ranged from 38.8% to 45.3% (Table 2). Tagged bass recaptures in the first year accounted for 87% of the total returns and ranged from 34.1% to 38.1% of numbers released. The last tagged smallmouth and largemouth bass recaptures were made on 22 August, 1987 and 12 July, 1987, respectively.

TABLE 2. Shasta Lake Tagged Bass Recaptures.

	Smallmouth Bass				*Largemouth Bass*			
Recapture	*Bridge Bay*		*Silverthorn*		*Bridge Bay*		*Silverthorn*	
Year	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
First Year	43	34.1	128	34.5	15	36.6	16	38.1
Second Year	9	7.1	14	3.8	1	2.4	2	4.8
Third Year	0	0	2	0.5	1	2.4	1	2.4
Totals	52	41.2	144	38.8	17	41.4	19	45.3

Smallmouth Bass Movement

Smallmouth bass released at both sites were recaptured at widespread locations. A clustering of recaptures occurred in areas where fishing effort is known to be relatively high, which included areas near the release sites (Figure 1). Of 180 tagged smallmouth bass returns for which recapture information was available, 23 (12.8%) were caught less than 1.6 km from the release sites while 157 (87.2%) were caught from 1.6 to 30.6 km from the release sites (Figure 2).

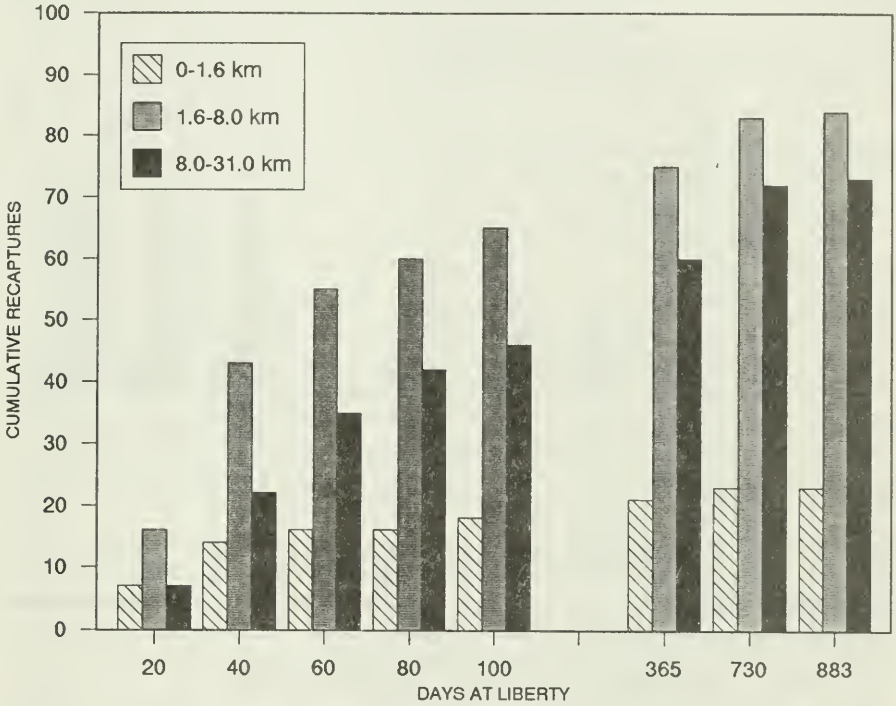

FIGURE 2. Cumulative recaptures of tagged smallmouth bass showing distances traveled from release sites and time at liberty.

The average distances from the release sites for smallmouth bass recaptures were 5.8 km in the first 20 days and 8.5 km for the entire study period. There were four smallmouth bass that moved at least 17.7 km each in 10–18 days.

Largemouth Bass Movement

Largemouth bass recaptures occurred mainly near the release sites (Figure 1). Of 34 tagged largemouth returns, 13 (38.2%) were caught less than 1.6 km from the release sites while 21 (61.8%) were caught from 1.6–17.7 km from the release sites (Figure 3). Average distances from release sites were 2 km in the first 40 days and 3.5 km during the entire study period. One largemouth bass moved 6.4 km in 14 days.

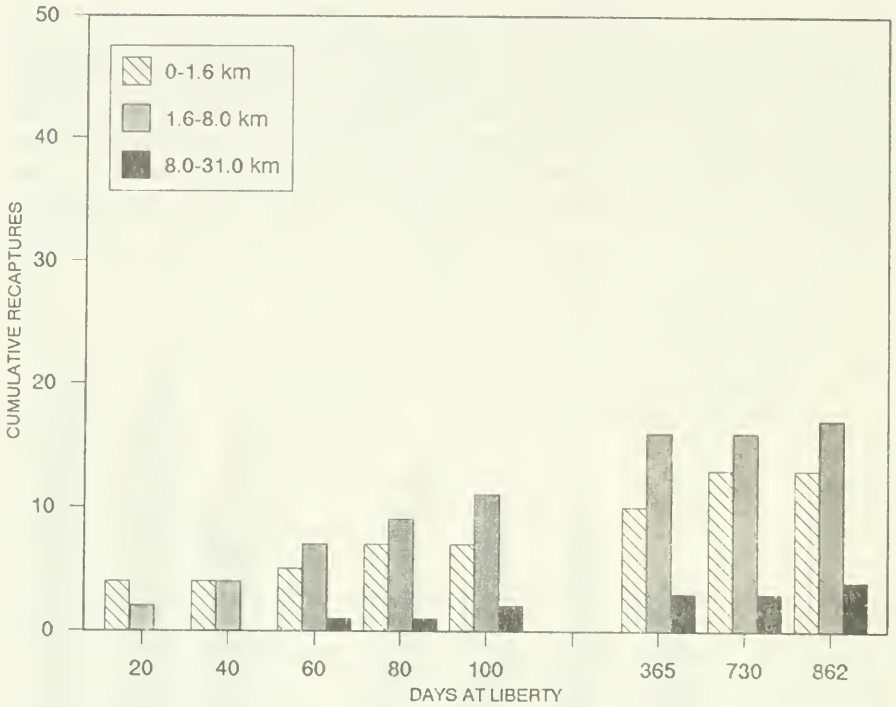

FIGURE 3. Cumulative recaptures of tagged largemouth bass showing distances traveled from release sites and time at liberty.

Estimated Survival of Tagged Bass

Annual survival rates were calculated at 0.13 (S=25/194) for smallmouth bass and 0.15 (S=5/34) for largemouth bass.

DISCUSSION AND CONCLUSIONS

Since only three smallmouth and no largemouth bass were recaptured during the first 10 days after release, tagged bass apparently were not vulnerable to angling shortly after release.

First year and total harvest rates were fairly uniform for all release groups and were considered to be high for non-reward tagged fish.

More than 87% of the smallmouth bass dispersed and were recaptured at least 1.6 km from the release sites which is consistent with the findings of others who have conducted similar studies. For example, Larimore (1952) observed relocated stream-dwelling smallmouth bass and found that many returned to their home pools. Forney (1961) noted that smallmouth bass released 8 to 24.1 km from an initial capture area in Oneida Lake, New York, traveled an average of 6.8 km to 12.4 km before recapture, while bass released within 4.0 km from their initial capture locations traveled only 3.9 km. Blake (1981) observed greater movement of tournament-caught smallmouth bass that had been displaced compared to bass that were caught and released at initial capture locations on the Saint Lawrence River. Pflug and Pauley (1983) found that 79% of the smallmouth bass that had been relocated from 0.8 to 11.3 km away from

initial capture locations in Lake Sammamish, Washington, moved away from their new release site before recapture. They also reported that 41% of the relocated tagged bass were able to travel up to 9.7 km to return to their initial capture locations, while 80% of the bass that were released where initially captured showed little or no movement. In this study, smallmouth bass moved an average distance of 8.5 km, which is considerably greater than the averages of 3.9 km and 1.1 km reported by Forney (1961) and Rawstron (1967), respectively, for smallmouth bass that were not displaced.

The results of this and other smallmouth bass displacement studies indicate that tournament-caught smallmouth bass released at a common weigh-in site can be expected to disperse naturally.

Largemouth bass in this study moved an average of 3.5 km from the release sites which is greater than the 1.9 and 1.1 km averages reported by Fisher (1953) and Rawstron (1967), respectively, for largemouth bass that were tagged and released where initially captured. The Shasta Lake average is comparable to the 3.7 km average observed by Kimsey (1957) for some tagged groups but less than the overall average of 7.2 km. Kimsey noted that angler reporting errors may have affected his migration data to indicate greater movement than actually occurred. Forty-one percent of the largemouth bass recaptures in this study occurred within 1.6 km of the release sites, which is similar to the results of Blake (1981), who reported that 44% and 52% of the returns of displaced tournament-caught largemouth bass in the Saint Lawrence River occurred within 1.6 km of the release sites during two tests in successive years.

Since largemouth bass did not move as far or disperse as quickly from the release sites as smallmouth bass, it may be appropriate for tournament sponsors to transport largemouth bass well away from weigh-in sites, especially where repeated tournaments are held, if it can be done without reducing survival.

The annual survival rates of 0.13 for smallmouth bass and 0.15 for largemouth bass in this study were low compared to survival rates noted in other studies (Table 3). Low survival rates were also reported at Shasta Lake for both smallmouth and largemouth bass by Van Woert (1980) and were attributed to high angler exploitation of both species.

TABLE 3. Comparative Annual Survival Rates of Smallmouth (SMB) and Largemouth Bass (LMB) noted in Selected Waters.

Name of Water	*Species*	*Annual Survival*	*Reference*
Shasta Lake	SMB	0.13	This study
Shasta Lake	"	0.10–0.18 [1]	Van Woert (1980)
Merle Collins Res.	"	0.16	Pelzman et al (1980)
Oneida Lake	"	0.40–0.82	Forney (1961; 1972)
Lake Michigan	"	0.42	Latta (1963)
Shasta Lake	LMB	0.15	This study
Shasta Lake	"	0.22	Van Woert (1980)
Don Pedro Res.	"	0.29	Horton and Lee (1982)
Merle Collins Res.	"	0.08–0.29	Rawstron et al (1972)
Folsom Lake	"	0.11	Rawstron (1967)
Sutherland Res.	"	0.30	La Faunce et al (1964)
Gladstone Lake	"	0.40	Maloney et al (1962)
Clear Lake	"	0.44	Kimsey (1957)
Sugarloaf Lake	"	0.30	Cooper and Latta (1954)

[1] Annual survival rates for smallmouth bass 306–356 mm fl.

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COMPARISON OF STEELHEAD CAUGHT AND LOST BY ANGLERS USING FLIES WITH BARBED OR BARBLESS HOOKS IN THE KLAMATH RIVER, CALIFORNIA [1]

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Klamath River anglers lost fewer steelhead *Oncorhynchus mykiss* on barbed hooks than on barbless hooks, regardless of fish size. Losses from barbed hooks of sizes 8 and 6 did not differ with fish size. Significantly fewer "half-pounders" (<406 mm long) were lost from barbless hook flies of size 6 than size 8. For adult steelhead (≥ 406 mm long) the loss rate was the same for flies with barbless hooks of size 6 and 8.

INTRODUCTION

Trout fisheries managed for catch-and-release fishing are increasing, and are popular with trout anglers (Graff 1987). The California Department of Fish and Game, which manages 17 streams and 7 lakes as catch-and-release fisheries restricted to artificial lures has recently added a "single barbless hook only" regulation for these waters—primarily to reduce mortalities (Deinstadt 1987).

Many fly anglers, regardless of regulations, fish with barbless hooks because they feel that captured trout are easier to release. Other anglers prefer flies with barbed hooks because they believe fish are not hooked as deeply and are less likely to be injured. Although many investigators have compared the hooking mortality of trout caught on barbed and barbless hooks (Wydowski 1977; Dotson 1982; Mongillo 1984; Titus and Vanicek 1988), the catch efficiencies of barbed and barbless hooks have not been rigorously compared—although Knutson (1987) reported that barbless hooks were as efficient as barbed hooks in catching all sizes of salmon taken by charter boat anglers fishing off the California coast.

The objective of this study was to compare numbers of Klamath River fall-fun steelhead, *Oncorhynchus mykiss,* caught and lost by fly anglers, by hook type (barbed or barbless, size 6 or size 8), and fish size ("half-pounder" or adult).

STUDY AREA

The Klamath River, in northwestern California, is an important salmon and steelhead stream. Fall-run steelhead provide a popular sport fishery from August to October (Kesner and Barnhart 1972). This fishery is primarily for small steelhead called "half-pounders", along with some adult steelhead. Half-pounders are unique in being on their first upstream migration after only a few months in the ocean. They are immature and survivors return to the ocean, grow, and migrate upstream in the following year as maturing adults (Kesner and Barnhart 1972, Everest 1973). Half-pounders are popular with anglers because of their willingness to strike and their fighting qualities. This investiga-

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tion was confined to the lower 40 km of the river above Klamath, California, where access is primarily by boat; it is not a catch-and-release water.

METHODS

Local fishing guides agreed to encourage their clients to participate in this study. A form was provided for each angler each day to record the number of half-pounders and adult steelhead caught or lost with barbed- or barbless-hook flies of size 6 or 8. Steelhead less than 406 mm (16 inches) in total length were considered half-pounders. Anglers were asked to fish with barbed or barbless hooks for half the fishing day and then to switch to the alternate choice for the rest of the day, in an effort to eliminate variability due to differences in angler skill. A "fish lost" was defined as one that escaped the hook at any time from the initial hooking to the beginning of the time when the angler had the fish under control and was trying to grasp, net, or bank the fish to release or keep it. A strike or bite did not count as a fish lost.

I used goodness of fit tests with log linear models and chi-square contingency tables (Sokal and Rohlf 1981) to test the null hypothesis that numbers of fish caught or lost were independent of hook type and fish size.

RESULTS AND DISCUSSION

Angling data were collected from August 17 to November 7, 1988. During this period daytime water temperatures ranged from 14° to 22°C; they were highest in August and lowest in November. The total of 48 anglers who participated hooked 1,914 steelhead, of which 1,372 were caught and 542 lost (Table 1).

TABLE 1. Steelhad Caught or Lost on Flies, Arranged by Hook Type (Barbed, Barbless, Sizes 8 and 6) and Fish Size (Half-Pounder, Adult), Klamath River 1988.

Hook type and fish size	*Total fish hooked*	*Caught (No.)*	*Lost*	
			No.	*Percent*
Barbed 8				
Half-pounder	244	184	60	25
Adult	42	35	7	17
Total	286	219	67	23
Barbed 6				
Half-pounder	402	311	91	23
Adult	84	72	12	14
Total	486	383	103	21
Barbless 8				
Half-pounder	365	225	140	38
Adult	31	21	10	32
Total	396	246	150	38
Barbless 6				
Half-pounder	667	470	197	30
Adult	79	54	25	32
Total	746	524	222	30
Totals	1914	1372	542	28

Analyses of the data showed that the numbers of steelhead caught and lost were not independent of hook type (G value 34.99, $p < 0.005$, 6 df) and that fewer fish, regardless of size, were lost from barbed hooks than from barbless hooks (G value 26.3, $p < 0.005$, 2 df). For half-pounders, hook sizes combined, 23% of the fish hooked on barbed hooks were lost and 33% of those hooked

on barbless hooks were lost ($p < 0.005$). For adult steelhead, hook sizes combined, 15% of the fish hooked on barbed flies and 32% of those hooked on barbless flies were lost ($p < 0.005$).

Analyses of the catch-loss rate by hook size showed no significant difference for barbed hooks for either half-pounders or adults (Table 1, G value 0.46, 2df). However, for barbless flies, significantly fewer half-pounders were lost from size 6 hooks (30%) than from size 8 hooks (38%); G value 28.53, $p < 0.005$, 2 df. For adult steelhead the catch-loss rate was the same for barbless hooks, regardless of hook size (32% lost).

The actual differences in numbers of fish lost per fishing day may not be important to many Klamath River fly anglers, because many release most or all of the fish caught. The creel limit for steelhead is three fish. If a fly angler hooked 10 half-pounders and 5 adult steelhead during a day's fishing, an average of 2 half-pounders and 1 adult would be lost from barbed hooks and 3 half-pounders and 2 adults lost from barbless hooks.

The use of barbless hook regulations to reduce fish mortality in catch-and-release waters appears to be valid. In addition to possibly reducing the mortality of landed fish through easier hook removal and reduced handling, the regulation may provide additional protection for fish because fewer trout are landed. The regulation should also help to distribute the catch among more anglers.

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ESTABLISHMENT OF RED SHINER, *NOTROPIS LUTRENSIS,* IN THE SAN JOAQUIN VALLEY, CALIFORNIA [1]

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Red shiner, *Notropis lutrensis,* recently introduced into the San Joaquin Valley, California are spreading throughout the Valley floor. Densities of shiner were highest in irrigation canals and drains, and other small, shallow, unstable aquatic habitats that were strongly influenced by agricultural and other human-related activities. These habitats were characterized by elevated turbidity, conductivity, total dissolved solids, total alkalinity, and total hardness. Fish species closely associated with red shiner were common carp, *Cyprinus carpio,* threadfin shad, *Dorosoma petenense,* mosquitofish, *Gambusia affinis,* inland silverside, *Menidia beryllina,* striped bass, *Morone saxatilis,* fathead minnow, *Pimephales promelas,* and Sacramento blackfish, *Orthodon microlepidotus.* All of these species are generally able to tolerate the harsh conditions present in many streams and rivers on the Valley floor. Limited observations on the life history of red shiner in the Valley showed them to be similar to endemic populations in the Mississippi River basin. Adults (mostly fish in their second growing season) were reproductively active from April to October. Major foods of these fish included filamentous algae and aquatic insect larvae. However, red shiner in irrigation drains and canals on the Valley floor also consumed terrestrial ants (Formicidae). The species is expected to eventually spread through the entire lower San Joaquin River system.

INTRODUCTION

Red shiner, *Notropis lutrensis,* are native to midwestern streams in the Mississippi River and Rio Grande drainages (Moyle 1976). In California, this fish has occurred in the Colorado River since at least 1953, presumably through bait minnow releases (Hubbs 1954). From the Colorado River, red shiner have moved into freshwater irrigation drains around the edge of the Salton Sea. In 1985, red shiner were also discovered in Big Tujunga Creek and in Coyote Creek at the upper end of Newport Bay within the Los Angeles basin of southern California (Los Angeles County Museum of Natural History; LACM 44507-2, 44508-1, 44509-1, 44510-1, 44522-2). However, attempts to establish the species elsewhere in the State as a source of live bait have generally been unsuccessful (Kimsey and Fisk 1964, Moyle 1976, McGinnis 1984).

Red shiner were first observed in the San Joaquin Valley when Wang (1986) collected an unspecified number of juvenile and adult fish in Millerton Lake, Fresno County, from 1980 to 1982. During July 1981, a single fish was collected from the San Joaquin River near Firebaugh, Fresno County (Saiki 1984). From May to July 1984, Ohlendorf et al. (1987) obtained three composite samples of red shiner from unspecified locations in the Grassland Water District (Grasslands), Merced County, about 30 km northwest of Firebaugh, for analysis of trace elements and pesticide residues. In September 1984 and again in

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September 1985, red shiner were collected in the Grasslands from Agatha Canal, Camp 13 Ditch, and Mud Slough at Gun Club Road (M.K. Saiki, unpubl. data). Additionally, unpublished field notes from the California Department of Fish and Game (CDFG) indicated that three adult red shiner were collected on 29 July 1985 from Los Banos Creek, about 2 km upstream from the Los Banos Detention Reservoir, Merced County (C. J. Brown, Jr., Associate Fishery Biologist, CDFG, pers. comm.). This locality is about 20 km west of the Grasslands.

Here we report the results of an extensive field survey conducted in 1986, with supplemental collections made in 1987, that document the distribution of red shiner in the San Joaquin River and selected tributaries on the Valley floor. We also present data on the morphometrics and ecology of this recently established population, including observations on reproductive characteristics, age, growth, and food.

MATERIALS AND METHODS

A total of 27 sites were intensively sampled for red shiner in September–November 1986, and additional collections were made for morphometric analyses of specimens from eight of the sites in February–May 1987 (Figure 1). All fish were collected with bag seines (6.4-mm mesh wing and 3.2-mm mesh bag, bar measure) and backpack electrofishing gear. To compute catch-per-effort statistics for the 1986 collections, we made all seine hauls parallel to shore over a standard distance of about 15 m, and electrofishing was conducted for at least 10 min (the actual time spent in electrofishing was recorded).

During the 1986 collections, we measured the following environmental variables at each site: current, water temperature, pH, turbidity, dissolved oxygen, total alkalinity, conductivity, total dissolved solids, stream width, stream depth, and the particle size distribution of bottom sediments. Schoklitsch's sediment factor, *s*, was computed from the sediment data with a standard formula described by Bogardi (1974). We estimated the percentages of pools, riffles, and runs at each site by using the "ocular" method described by Pfankuch (1975). We also used this method to estimate the percentage of cover provided by emergent and submerged vegetation. Finally, we assigned each site a subjective rating of 1–5 (with 1 being the lowest) that characterized the extent of "human impact" (e.g., channelization, removal of riparian cover, and water flow diversions) as perceived by one of us (M.R.J.), an experienced field observer.

All captured fish were identified, counted, and except for representative samples preserved in 10% formalin, returned to the water. Preserved samples were kept for counts of fin rays and scales (Hubbs and Lagler 1958); and determinations of fecundity (Bagenal and Braum 1978), age and growth (Bagenal and Tesch 1978), and stomach contents (Windell and Bowen 1978).

Before conducting analysis-of-variance (ANOVA) tests, we logarithmically transformed all catch-per-effort values to best meet the assumptions (i.e., symmetry, equal variances among groups, linearity, and additive structure) of the statistical procedure. We accepted the level of significance as being $P \leq 0.05$ unless otherwise indicated. When F-statistics were significant, we conducted Tukey-Kramer "honestly significant difference" (hsd) tests to compare geo-

metric means for statistical differences. We calculated Spearman's rank correlations (r_s) to identify significant statistical associations between the abundance of red shiner and various ecological characteristics (i.e., water quality and hydrological measurements, and the abundance of other fish species).

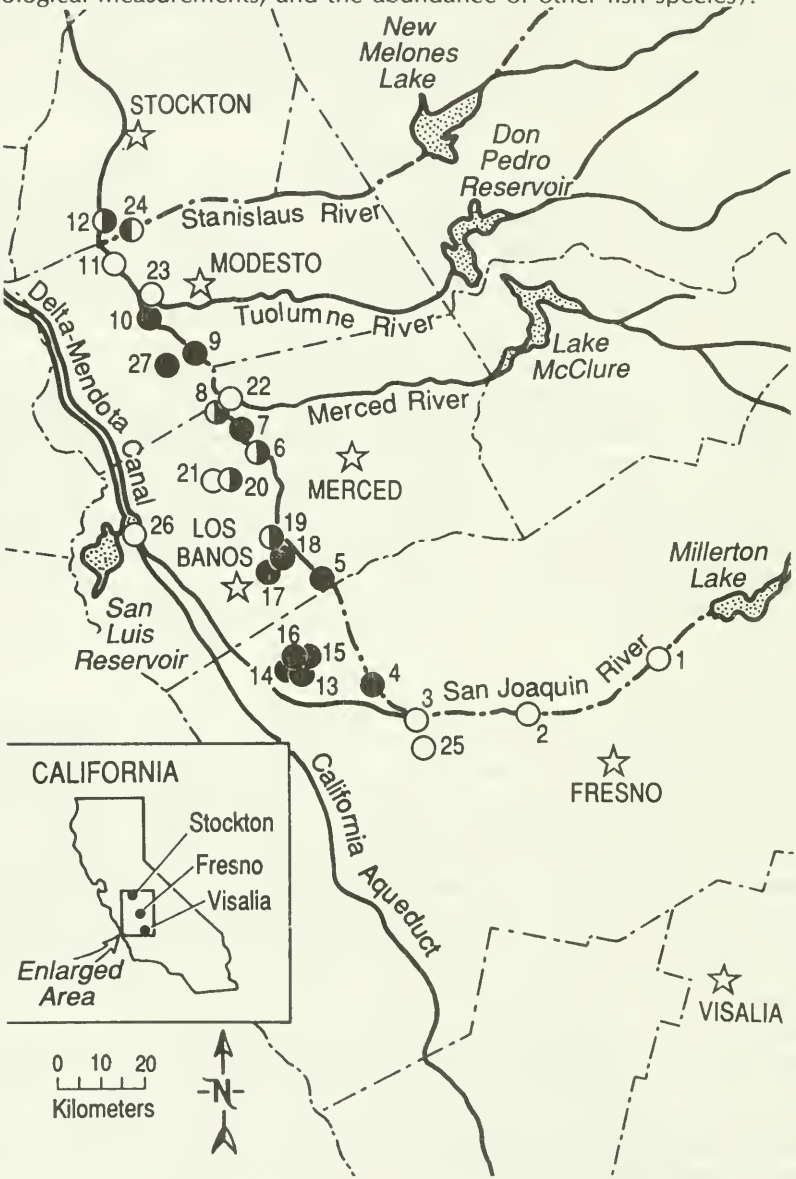

FIGURE 1. Locations of sampling sites in the study area, and abbreviations used in Table 1: (1) San Joaquin River near Fort Washington Road, (2) San Joaquin River at Hwy 145, (3) San Joaquin River at Mendota Pool, (4) San Joaquin River at Firebaugh, (5) San Joaquin River at Hwy 152, (6) San Joaquin River at Lander Avenue, (7) San Joaquin River at Fremont Ford State Recreational Area, (8) San Joaquin River at Hills Ferry

Continued

Road, (9) San Joaquin River at Crows Landing Road, (10) San Joaquin River at Laird County Park, (11) San Joaquin River at Maze Road, (12) San Joaquin River at Durham Ferry State Recreation Area, (13) Helm Canal, (14) Main Canal, (15) Agatha Canal, (16) Camp 13 Ditch, (17) Mud Slough at the Los Banos Wildlife Area, (18) Salt Slough at Hereford Road, (19) Salt Slough at the San Luis National Wildlife Refuge, (20) Mud Slough at Gun Club Road, (21) Los Banos Creek at Gun Club Road, (22) Merced River at George J. Hatfield State Recreational Area, (23) Tuolumne River at Shiloh Road, (24) Stanislaus River at Caswell Memorial State Park, (25) Fresno Slough, (26) Delta-Mendota Canal at O'Neill Forebay, and (27) Crow Creek at Hwy 33. Localities where red shiner were collected in September–November 1986 are denoted by filled circles; in February–May 1987, by left-hand filled circles; in both 1986 and 1987, by right-half filled circles; and, where never collected, by unfilled circles.

RESULTS AND DISCUSSION

We collected 1,341 red shiner at 17 of 27 sites on the San Joaquin Valley floor in September–November 1986 (Figure 1). An additional 800 specimens were collected at 6 of 8 sites in February–May 1987, with one of these sites representing a new occurrence of the species (Figure 1), thus bringing the total number of sites containing red shiner to 18.

Morphological examination of 125 specimens from 17 sites indicated that they most resembled *Notropis lutrensis lutrensis*. Adults >25 mm total length (TL) were relatively deep bodied and closely matched the descriptions by Hubbs and Ortenburger (1929). Average lateral line scale counts were 34.5 (range, 33–36), and anal fin rays 9 (range, 8–10) in over 80% of the fish examined. Our specimens differed from the Colorado River populations of *N. l. lutrensis* X *N. l. suavis* intergrades (described by Hubbs 1954) in having a "chunkier" body shape and higher lateral line scale counts. However, the possibility of hybrid populations of *N. lutrensis* in the San Joaquin Valley cannot be ruled out. Additional studies (e.g., Matthews 1987) on the geographical variation of native populations of *N. lutrensis* in the Midwest might assist in identifying the probable origin of the San Joaquin Valley population. Voucher specimens from all sites were deposited in collections at the Museum of Zoology, University of Michigan (UMMZ 213990–214006).

Abundance and Distribution

Red shiner were most abundant in irrigation canals and drains of the Grasslands (e.g., Agatha and Main canals, Camp 13 Ditch, and Mud and Salt sloughs), followed by sites on the San Joaquin River that were adjacent to the Grasslands or downstream from tributaries that drain the Grasslands (e.g., from Firebaugh to Durham Ferry State Recreation Area; see Table 1). We also collected about 20 specimens in September 1987 from Crow Creek, an intermittent stream that flows into the San Joaquin River about 15 km downstream from the Grasslands. Although we collected a single fish in March 1987 from the Stanislaus River, red shiner were seemingly lacking in tributaries that drain the east side of the San Joaquin Valley and from the southern end of the Valley floor (Table 1).

TABLE 1. Abundance of Red Shiner from 26 Sites on the San Joaquin Valley Floor as Determined by Electrofishing (Numbers of Fish per 10 Min of Fishing) and Bag Seining (Numbers of Fish per 15-m Haul) in Sept.–Nov. 1986. Within Regions, Sampling Sites are Tabulated in Approximate Longitudinal (Upstream–Downstream) Sequence; Refer to Figure 1 for Names and Locations of Sites. Values are expressed as Unweighted Geometric Means for Each Region and Site. Means in Each Column Followed by the Same Capital Letter are not Significantly Different ($P > 0.05$, Tukey-Kramer hsd Test). Values in Parentheses Indicate Number of Observations.

Region and site	*Electrofishing*	*Bag seining*
San Joaquin River:		
27	0.0	0.0
16	0.0	0.0
1	0.0	0.0
2	0.0	1.7
8	0.0	0.6
18	0.7	0.0
20	4.0	0.0
17	5.3	0.0
21	0.8	1.3
22	0.2	0.0
24	0.0	0.0
25	0.5	0.4
	0.7 B (n=33)	0.3 B (n=62)
Grassland Water District:		
7	5.5	0.5
4	0.3	0.0
5	4.1	5.5
6	25.6	0.0
13	0.0	0.0
9	4.2	0.2
10	—[a]	0.4
11	4.3	0.7
12	58.8	1.7
	3.9 A (n=23)	0.8 A (n=53)
Eastern tributaries:		
19	0.0	0.0
23	0.0	0.0
26	0.0	0.0[b]
	0.0 B (n=7)	0.0 B (n=15)
Other tributaries[c]:		
15	0.0	0.0
3	0.0	0.0
	0.0 B (n=6)	0.0 B (n=10)
F (df1,df2)[d]	6.77**	4.65**

[a] No data.

[b] One red shiner was collected from this site in February–May 1987.

[c] One site (14) was omitted because fishing effort was not quantified.

[d] For electrofishing, df1 = 4, df2 = 64; for bag seining, df1 = 4, df2 = 135. $^{**}P \leq 0.01$.

Relation to Water Quality and Hydrology

The ranges of geometric means of selected hydrological variables at 16 of the 18 sites where red shiner were collected are presented in Table 2. These measurements reveal the variable influence that irrigation return flows, which typically contain high concentrations of suspended sediments, agricultural fertilizers, other dissolved salts, and animal wastes (Sylvester and Seabloom 1963, Miller et al. 1978), had on the aquatic habitats that we sampled.

TABLE 2 Ranges of Geometric Means of Selected Hydrological Variables at 16 of the 18 Sites in the San Joaquin Valley Where Red Shiner were Collected.

Hydrological variable	*Range*
Stream width	4–80 m
Average water depth	0.3–4.3 m
Maximum water depth	0.3–5.7 m
Current velocity	<0.01–0.52 m/sec
Water temperature	12–22°C
Turbidity	2.3–26 NTU's
Conductivity	141–2,453 μmhos/cm @ 25°C
Total dissolved solids	80–1,600 mg/L
pH	6.9–8.0
Dissolved oxygen	7.5–9.6 mg/L
Total hardness	44–527 mg/L as $CaCO_3$
Total alkalinity	49–200 mg/L as $CaCO_3$

The abundance of red shiner was positively correlated with turbidity, pH, conductivity, total alkalinity, total hardness, total dissolved solids, percentage of runs, and degree of human impact, and negatively correlated with maximum stream depth and stream width (Table 3). Several investigators (e.g., Matthews and Hill 1977, 1979; Becker 1983; Matthews 1986) reported that many red shiner populations in the plains states of the Midwest seem to thrive under conditions of intermittent flow, high temperatures, high turbidity, and other harsh environmental conditions similar to those in the San Joaquin Valley.

TABLE 3. Spearman's Rank Correlations (r_s) Between Various Ecological Variables and the Abundance of Red Shiner as Determined by Electrofisihing (Numbers of Fish per 10 Min of Fishing) and Bag Seining (Numbers of Fish per 15-m Haul) [a].

Ecological parameter	*Electrofishing*	*Bag seining*
Water quality		
Dissolved oxygen	−0.07	−0.10
pH	0.39*	0.29
Total alkalinity	0.62**	0.56**
Total hardness	0.74**	0.60**
Total dissolved solids	0.72**	0.60**
Conductivity	0.75**	0.59**
Temperature	0.13	−0.06
Turbidity	0.58**	0.23
Hydrology		
Current velocity	0.15	−0.07
Stream depth	−0.19	0.36
Maximum stream depth	−0.32	−0.48**
Stream width	−0.47*	−0.15
Sediment factor, *s*	−0.17	0.08
Pool (%)	−0.05	−0.14
Riffle (%)	−0.22	−0.03
Run (%)	0.50**	0.16
Other		
Emergent vegetation (%)	−0.04	−0.03
Submerged vegetation (%)	−0.03	−0.01
Human Impact	0.40**	0.02

[a] Codes: * $P \leq 0.05$; ** $P \leq 0.01$.

Relation to Other Fishes

The abundance of red shiner was correlated positively with the abundance of common carp, *Cyprinus carpio,* threadfin shad, *Dorosoma petenense,* mosquitofish, *Gambusia affinis,* inland silverside, *Menidia beryllina,* striped bass, *Morone saxatilis,* fathead minnow, *Pimephales promelas,* and Sacramento blackfish, *Orthodon microlepidotus,* and negatively with the abundance of

redear sunfish, *Lepomis microlophus,* as shown in Table 4. However, we did not determine if these patterns were due to the environmental requirements and tolerances of the different species, dynamic ecological interactions (e.g., predator-prey relations, competition), or other factors. Red shiner are the fourth most abundant fish on the San Joaquin Valley floor after introduced threadfin shad, mosquitofish, and inland silverside (Jennings and Saiki, in prep.), and they are undoubtedly important prey for piscivorous fishes (Becker 1983). In some areas, red shiner have increased their range and, in the process, displaced other fishes with similar ecological requirements (Page and Smith 1970; Echelle et al. 1972; Minckley 1973; Cross 1978, 1985; Deacon 1988; Greger and Deacon 1988).

TABLE 4. Spearman's Rank Correlations (r_s) Between the Abundance of Various Fish Species and Red Shiner as Determined by Electrofishing (Numbers of Fish per 10 Min of Fishing) and Bag Seining (Numbers of Fish per 15-m Haul)[a].

Fish species	*Origin*[b]	*Electro-fishing*	*Bag seining*
Yellowfin goby, *Acanthogobius flavimanus*	I	0.28	—0.15
White sturgeon, *Acipenser transmontanus*	N	0.28	—[c]
American shad, *Alosa sapidissima*	I	0.34	—0.15
Goldfish, *Carassius auratus*	I	—0.02	0.37
Sacramento sucker, *Catostomus occidentalis*	N	0.36	—0.15
Prickly sculpin, *Cottus asper*	N	0.16	0.04
Common carp, *Cyprinus carpio*	I	0.39 *	0.17
Threadfin shad, *Dorosoma petenense*	I	0.63 **	0.09
Mosquitofish, *Gambusia affinis*	I	0.32	0.41 *
Tule perch, *Hysterocarpus traski*	N	0.34	—[c]
White catfish, *Ictalurus catus*	I	—0.23	0.32
Black bullhead, *I. melas*	I	0.07	—0.16
Brown bullhead, *I. nebulosus*	I	0.23	—[c]
Channel catfish, *I. punctatus*	I	0.09	0.24
Hitch, *Lavinia exilicauda*	N	0.32	0.18
Green sunfish, *Lepomis cyanellus*	I	0.14	0.24
Warmouth, *L. gulosus*	I	0.29	0.24
Bluegill, *L. macrochirus*	I	—0.37	—0.04
Redear sunfish, *L. microlophus*	I	—0.54 **	—0.06
Inland silverside, *Menidia beryllina*	I	0.40 *	0.23
Smallmouth bass, *Micropterus dolomieui*	I	—0.05	—0.22
Largemouth bass, *M. salmoides*	I	—0.16	—0.09
Striped bass, *Morone saxatilis*	I	0.50 **	0.25
Golden shiner, *Notemigonus crysoleucas*	I	0.07	0.06
Sacramento blackfish, *Orthodon microlepidotus*	N	0.34	0.46 *
Bigscale logperch, *Percina macrolepida*	I	—0.13	0.20
Fathead minnow, *Pimephales promelas*	I	0.63 **	0.47 *
Sacramento splittail, *Pogonichthys macrolepidotus*	N	0.28	—[c]
White crappie, *Pomoxis annularis*	I	0.26	—0.04
Black crappie, *P. nigromaculatus*	I	0.38	—0.11

[a] Codes: $*P \leq 0.05$; $**P \leq 0.01$.
[b] Codes: I, introduced; N, native.
[c] No data

There were no significant negative correlations between the abundance of red shiner and native fishes such as Sacramento sucker, *Catostomus occidentalis,* prickly sculpin, *Cottus asper,* tule perch, *Hysterocarpus traski,* hitch, *Lavinia exilicauda,* Sacramento splittail, *Pogonichthys macrolepidotus,* and Sacramento blackfish (Table 4). These data suggest that red shiner have not yet strongly influenced the distribution and abundance of native fishes on the Valley floor. However, the relative scarcity of the natives (< 25% of the total species; see Table 4) might be partly responsible for our failure to detect

significant correlations. Nonetheless, because red shiner are newly established in the San Joaquin Valley, the magnitude of their effects on native fishes might still be forthcoming.

According to McGinnis (1984), the native California roach, *Hesperoleucus symmetricus,* shares many ecological requirements with red shiner, and may be vulnerable to displacement by this newcomer. Despite considerable sampling, we collected no California roach on the Valley floor (also see Saiki 1984), suggesting that it is either absent or rare in Valley floor watercourses. However, California roach are present upstream at higher elevation sites in east side (Sierra Nevada foothill) tributaries such as the Merced and Tuolumne rivers (Moyle and Nichols 1974; M. K. Saiki, unpubl. data). Red shiner are expected to move into these eastside habitats but, as of May 1987, they were not found in the Merced and Tuolumne rivers, and only one specimen was collected from the Stanislaus River. Therefore, any effects of red shiner on California roach remain unknown.

Life History Observations

Reproduction

Adult males in breeding coloration (orange-red caudal, pelvic, anal, and pectoral fins) were observed in the San Joaquin Valley during September–October 1986 and April–May 1987. Cross (1967) and Farringer *et al.* (1979) wrote that red shiner in Kansas, Texas, and Oklahoma spawn at water temperatures of 15.6–29.4°C from May to October, with most spawning probably occurring in June and July. Wang (1986) estimated that spawning occurred during June and July in Millerton Lake in the San Joaquin Valley.

We examined 11 gravid females ranging in total length from 42 to 55 mm, and counted 1,177 to 5,411 eggs per fish (geometric mean, 2,205 eggs). These counts were nearly fourfold higher than those reported for red shiner in central Iowa (Laser and Carlander 1971). We found no significant correlation between the number of eggs and female length ($r_s = -0.27$, df = 9), a result also reported by Laser and Carlander (1971). Because red shiner are "fractional" spawners (Gale 1986), females may release their eggs on several occasions between April and October in the San Joaquin Valley; this spawning pattern might obscure associations between the number of eggs and size of females.

Age and Growth

As judged from cursory scale examinations of 25 fish, the oldest red shiner in our collections had two complete annuli (i.e., the specimen was in its third growing season). We found three gravid young-of-the-year females, but the remaining gravid females were in their second growing season. Similar findings were reported by Carlander (1969), Laser and Carlander (1971), and Wang (1986).

The length-weight relation of 2,008 red shiner (TL 10–66 mm) from our study was best described ($r^2 = 0.97$) by the equation

$$\log_{10} W = 0.0000032 + 3.284678 \log_{10} L$$

where W is the mass of the fish (g) and L is the TL (mm).

Food

We examined the stomach contents of 100 red shiner from 17 sites and noted mostly filamentous algae and aquatic insect larvae (Table 5). Other researchers (e.g., Cross 1967, Hardwood 1972, Minckley 1973, Becker 1983, Wang 1986, Greger and Deacon 1988) have reported similar omnivorous diets for this fish. Although red shiner consume filamentous algae, the food value of algae is doubtful because of its apparently low digestibility (Becker 1983).

TABLE 5. Food Organisms in 79 of 100 Red Shiner Collected from 17 Localities in the San Joaquin Valley, California.

Taxa	*Occurrence* (%)	*Volume* (%)
Plants		
Chlorophyta		
Chlorophyceae		
Zygnematales		
Zygnemataceae	50.0	10.1
Mesotaeniaceae	15.0	3.0
Desmidiaceae	35.0	6.3
Euglenophyta		
Unknown	1.2	0.1
Chrysophyta		
Bacillariophyceae		
Pennales	36.0	7.8
Tracheophyta		
Spermopsida		
Angiospermae	5.8	1.7
Animals		
Rotatoria		
Monogonota		
Floscularicea	2.3	0.2
Annelida		
Oligochaeta		
Plesiopora	7.0	5.1
Arthropoda		
Crustacea		
Cladocera	2.3	1.8
Copepoda	2.3	0.8
Arachnida		
Araneae	2.3	1.4
Insecta		
Trichoptera		
Hydropsychidae	3.5	1.8
Hymenoptera		
Formicidae	15.1	10.4
Unknown	1.2	0.3
Coleoptera	1.2	1.3
Diptera		
Chironomidae	10.5	4.8
Unknown	14.0	10.1
Unknown	44.2	31.8
Chordata		
Osteichthyes		
Cypriniformes	1.2	1.2

Additionally, we observed that terrestrial ants (Formicidae) contributed >50% (by volume) of the total diet of red shiner collected from irrigation canals and drains in the Grasslands (for fish from all sites combined, however, ants contributed only 10.4% of the total diet; see Table 5). The importance of ants as forage for fish in the Grasslands was probably due to the profusion of overhanging grasses and other locally abundant ditchbank vegetation frequented by ants.

CONCLUSIONS

The rapid spread of red shiner in the San Joaquin Valley parallels the explosive population growth of this baitfish in other areas of California, Arizona, and Nevada where it has been introduced (Minckley 1973, Moyle 1976, Cross 1985, Greger and Deacon 1988). The previous omission of this species as a major component of the ichthyofauna from the San Joaquin Valley floor is probably due to its recent establishment in the Valley, and its superficial resemblance to juvenile golden shiner, *Notemigonus crysoleucas,* and fathead minnow. We suspect that red shiner were first stocked into Millerton Lake and Grasslands waters in the late 1970's to early 1980's from the bait buckets of fishermen. From the latter locality, this species is now rapidly invading the lower San Joaquin River system, a process that may be aided by the extensive network of irrigation canals (especially the Delta-Mendota Canal) and drains in the Valley, and the indiscriminant use of live "minnows" by some bait fishermen.

In 1979, the California Citizen's Nongame Advisory Committee recommended to the CDFG that red shiner be removed from the list of allowable freshwater live bait species. In 1982, a report prepared by the CDFG (Gleason 1982) recommended that the use of this species as live bait in inland waters be limited to the Colorado River and Salton Sea. However, red shiner can still be legally used as live bait in many areas of California, including the northern San Joaquin Valley (i.e., north of Interstate 580 and State Highway 132, California Department of Fish and Game 1989). Furthermore, at least five aquacultural facilities are registered by the State of California for rearing this species in counties lying beyond the Colorado River-Salton Sea drainage, including one in Merced County (California Department of Fish and Game 1986). The documented establishment of this highly fecund species on the San Joaquin Valley floor, and recent reports of new populations in other portions of central and southern California, suggest that this baitfish should be prohibited from all waters in California where it is not yet established. We also suggest that red shiner not be cultured in drainages where its use as a live bait species is prohibited.

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NOTES

PRELIMINARY EXAMINATION OF LOW SALINITY TOLERANCE OF SPERM, FERTILIZED EGGS, AND LARVAE OF ORANGEMOUTH CORVINA, *CYNOSCION XANTHULUS*

Orangemouth corvina, *Cynoscion xanthulus,* native to the Gulf of California, were established through introductions from 1950 through 1955 into the Salton Sea, an inland saline lake in the southern California desert (Walker et al. 1961, Whitney 1961), where a successful sport fishery subsequently developed. Texas Parks and Wildlife Department (TPWD) obtained subadults from the Salton Sea in 1981 (Prentice and Colura 1984, Prentice 1985), 1984, and 1985 to develop spawning methodology and evaluate corvina as a predator in reservoirs containing large populations of *Tilapia* spp. and *Dorosoma* spp.

Progeny from tank-spawned corvina were successfully reared in saltwater hatchery ponds. After Prentice (1985) indicated subadult orangemouth corvina could be acclimated to fresh water (0.02 ‰ salinity), hatchery-produced juveniles were acclimated to fresh water and stocked in Calaveras Reservoir near San Antonio, Texas, where a substantial sport fishery developed.

Low salinity tolerance of sex products and very early life stages remained undefined, as did the possibility of natural reproduction in freshwater systems. Therefore, experiments were performed to examine the low salinity tolerance of orangemouth corvina spermatozoa, fertilized eggs, and yolk-sac larvae to provide insight into whether reproduction among reservoir-stocked fish could be expected, and if high salinity marine hatchery facilities were necessary for spawning and rearing of cultured orangemouth corvina.

Tests were conducted to evaluate the effects of low salinity on (i) sperm activity, (ii) fertilized egg incubation and hatching, and (iii) survival of larvae through the yolk-sac stage. Photoperiod-temperature manipulated orangemouth corvina (hormone-injected females) (Prentice and Thomas 1987, Prentice et al. 1989) and tank-spawned eggs were used as the source of study material. Salinity of 28.9 ‰ was considered the control value because it represented brood tank salinity where successful spawning, fertilization, and hatching had occurred. Test solutions were prepared with synthetic sea salt.

In sperm activation tests (Table 1, A–D), sperm was obtained from quinaldine-anesthetized males in a clean, dry pipette and held at 24°C for 5–56 min or 3°C for 30–50 min. Activation was attempted when a drop of one of nine test salinity solutions was mixed with a drop of milt on a clean, dry slide. Sperm activity duration was monitored in three of four tests. Activity in samples where sperm swam vigorously and where virtually all cells activated (as seen in the 28.9 ‰ salinity control) was considered good; activity was considered minimal in samples where sperm swam slowly or where only a few cells activated.

TABLE 1. Effect of Salinity on Activation and Activity Duration of *Cynoscion xanthulus* Spermatozoa in Four Tests, Heart of the Hills Research Station, Ingram, Texas, 1986. One Drop of Milt and a Drop of Test Solution was Mixed on a Glass Slide to Activate the Cells. Activity was Rated as Good When Most Cells Activated and Swam Vigorously, and as Minimal When Few Cells Activated or When They Swam Slowly (as Compared to Activity at 28.9 ‰ Salinity).

Parameter	*Salinity ‰* 28.9	18.9	13.3	7.2	2.2	1.7	1.2	0.6	0.0
					Test A (Range-finding)				
Time from removal [a] (min)	5					5			5
Activity duration (min)									
Slows									
Stops									
Activity rating	Good					Good			Good
					Test B				
Time from removal (min)	8	34	25	25	8	47	8	56	
Activity Duration (min)									
Slows		6.0	3.0	2.0			5.0	2.0	
Stops	7.0	5.0	abort [b]			6.0	2.1		
Activity rating	Good	Good	Minimal	None	None	Minimal	Good	None	
					Test C [c]				
Time from removal (min)	50	50	50	50	50	50	50	50	50
Activity duration (min)									
Slows	9.5	9.0	21.2						
Stops	13.9	10.0	24.7						
Activity rating	Good	Good	Minimal	None	None	None	None	None	None
					Test D				
Time from removal (min)	30	30	30	30	30	30	30	30	30
Activity duration (min)									
Slows	11.2	21.7	15.3						
Stops	21.0	30.0	28.7						
Activity rating	Good	Good	Minimal	None	None	None	None	None	None

[a] Time from removal from male donor until addition of test solution.

[b] Test was aborted because milt and test solution may not have been fully mixed at the start.

[c] Milt from males in tests C and D was refrigerated (3°C) between collection from the male and exposure to test solution (25°C).

In egg incubation tests, naturally fertilized eggs were taken from an external egg collector (Prentice and Colura 1984) attached to the brood tank. Viable eggs with developing embryos were selected and distributed by pipette at a rate of 36 per 90-x 20-mm Petri dish in 40 ml of one of 10 test solutions (Table 2) and maintained at 24–25°C. Water in test dishes was not aerated or exchanged during the 20.5-to 24.0-h observation period.

TABLE 2. Effect of Salinity on Hatching Success of *Cynoscion xanthulus* Eggs Incubated at 24–25°C, Heart of the Hills Research Station, Ingram, Texas, 1986. Test Salinity, Embryonic Stage at Start of Test, and Hours from Start of Test to Termination Are Given; All Groups Contained 36 Eggs. Eggs Were Obtained fromAdults Spawned in a Culture Tank at 24–24°C and 28.9 °/oo Salinity, and Were Abruptly Transfered from Culture Tank Salinity to Test Salinities.

Salinity (°/oo)	*Embryonic stage*	*Hours from start*	*Results*
30.0	15–16 somites	20.5	all hatch normally
28.9	tail-free	24.0	all hatch normally one dies after hatch
17.7	15–16 somites	20.5	all hatch normally
5.5	15–16 somites	20.5	all hatch normally
4.6	tail-free	24.0	23 hatch normally but do not move
3.9	tail-free	24.0	26 hatch normally but do not move
3.3	15–16 somites	20.5	hatch 1–2 h prematurely, all die
2.2	15–16 somites	20.5	hatch 1–2 h prematurely, all die
1.7	15–16 somites	20.5	hatch 1–2 h prematurely, all die
0.0	tail-free	24.0	hatch 3–4 h prematurely, all die
0.0	15–16 somites	20.5	hatch 3–4 h prematurely, all die

Larval survival tests employed recently hatched yolk-sac larvae (1–3 h old) which were removed from the brood tank and distributed by pipette at a rate of 10 per 90- x 20-mm Petri dish in 40 ml of one of eight test solutions (Table 3), and maintained at 24–25°C for 48 h. Larvae were transferred directly from incubation and hatching salinity of 28.9 °/oo to test salinities abruptly with no acclimation and as little transfer of brood tank water with each larvae as possible. Subsequent survival was monitored. No food was provided during the observation period and Petri dish water was not aerated or exchanged.

TABLE 3. Survival (Percent) of Yolk-Sac *Cynoscion xanthulus* Following Abrupt Transfer from 28.9 °/oo Hatching Salinity, Heart of the Hills Research Station, Ingram, Texas, 1986. Each Group Contained 10 Unfed Larvae Maintained at 24–25°C.

Salinity (°/oo)	*Hours past transfer*							
	0.0	*2.7*	*3.7*	*19.2*	*24.6*	*27.5*	*43.4*	*48.0*
28.9	100	100	100	100	90	80	70	30
18.9	100	100	100	90[a]	80	70	60[a]	30
13.3	100	90[a]	90	80	80	80	80	60
7.2	100	100	100	90	80[a]	80	70	50
2.2	100	100	100	100	80[a]	80	70	70
1.7	100	100	100	80	70[a]	70	60	60
1.2	100	100	100	80	80[a]	80	80	80
0.0	100	100	100	20	20	20	20	20
0.0	100	100	100	20	20	20	10	10

[a] Dead larvae were found trapped in the surface film, a factor that may have reflected more upon mortality than salinity.

Sperm activation test results indicated good activity on contact with 18.9 and 28.9 °/oo salinity water when tested within 5 to 34 min for milt held at 24°C, or 30 to 50 min for milt held at 5°C after removal from the male (Table 1). Activity continued in Test B for 5 to 7 min but lasted up to 30 min during other observations (Tests C–D). Minimal activation was obtained in both refrigerated and unrefrigerated milt samples at 13.3 °/oo salinity. While sperm activity was minimal at 13.3 °/oo salinity, activity lasted 24.7 to 28.7 min, longer than at higher salinities. Tests C and D, conducted when brood fish were near the end of their

reproductive cycle, produced no activation at any of the low salinities tested. However, Tests A and B, conducted when fish were just past their reproductive cycle peak, resulted in minimal to good activation at 1.2 and 1.7 ‰ salinities.

Eggs incubated at 5.5 ‰ salinity or above developed normally, hatched, and larvae progressed through the yolk-sac stage (Table 2). Eggs incubated at 3.9 and 4.6 ‰ salinity appeared to develop normally with 64 to 72% hatching. However, after hatching, these larvae remained motionless on the bottom of the culture dish. Although eight at 3.9 ‰ salinity and eight at 4.6 ‰ survived over 96 h, they were severely deformed with contorted notochords, malformed jaws, and yolk-sacs still present at death. In specimens incubated at 1.7, 2.2, and 3.3 ‰ salinities, all embryos were ejected from the chorion about 1–12 h prior to normal hatching. All were dead when observed. Eggs incubated at 0.0 ‰ ejected embroyos 3–4 h early and were also dead when observed.

Early yolk-sac larvae survived abrupt transfer from 28.9 ‰ incubation salinity to all test solutions with no immediate mortality (Table 3). The first mortalities were observed 19.2 h after transfer, excluding the loss of a single larvae at 13.3 ‰ salinity found trapped in the surface film after 2.7 h. Test salinities of 1.2 ‰ or greater had 30 to 80% survival after 48.0 h.

Results of these tests suggested successful orangemouth corvina reproduction can occur above about 13 ‰ salinity, and may occur at substantially lower salinities. Inconsistent sperm activity at 1.2 and 1.7 ‰ salinities may have reflected time between removal from the male and activation, or storage temperature during that time, or stage in the reproductive cycle when milt was obtained. Loss of access to brood fish prevented replication of this work. Duration of sperm activity suggests that in culture situations where adults are stripped, and milt and roe mixed, sufficient time should be allowed to obtain maximum fertilization. Short sperm motility periods of 35 sec to 2 min, often associated with artificial culture techniques (Bonn et al. 1976, Piper et al. 1982), could be extended in orangemouth corvina. Clearly though, additional information is needed on the effects of time, temperature and reproductive state on sperm activation and activity duration.

Eggs incubated from the 15- to 16-somite stage and older, developed and hatched at or above 5.5 ‰ salinity, with salinities below 5.5 ‰ causing premature hatching or deformed larvae. The impact, if any, of low salinity incubation from the moment of fertilization through hatching still needs to be examined.

Similarly, larval development, at least through the yolk-sac stage, proceeded well at or above 1.2 ‰ salinity. Whether these larvae would feed and continue to develop through the larval period and transform normally to the juvenile stage also remains to be examined.

Brocksen and Cole (1972) suggested metabolic problems limit growth rate in young-of-the-year below 32 ‰ salinity; however, experimental work with orangemouth corvina in the laboratory (Prentice 1985) and with orangemouth corvina and their hybrids with spotted seatrout, *C. nebulosus,* in a freshwater reservoir (TPWD, Austin, unpubl. data) have shown good survival and growth in fresh water.

Mortalities recorded for larvae after 20–30 h, when yolk-sac absorption normally occurs and exogenous feeding should begin, may be more a function

of starvation than of salinity. Higher survival rates after yolk-sac absorption might have occurred had test specimens been fed.

Even if moderate to high salinity water was required for orangemouth corvina reproduction, eggs can be transferred to lower salinities, and recently hatched larvae to still lower salinities. This suggests implications in fish culture facilities where brood fish may be spawned in saltwater tanks, but where larvae can be transferred to very low salinity rearing ponds like those that exist at some hatcheries both in Texas and California. Lastly, it should be noted that salinity changes described for eggs and larvae here were abrupt; slow acclimation to low salinity could possibly provide decreased stress with subsequent increased long-term survival.

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BOOK REVIEWS

THE STARRY ROOM
NAKED EYE ASTRONOMY IN THE INTIMATE UNIVERSE
By Fred Schaaf. John Wiley & Sons, Inc., New York, NY, 1988. vi+264 p. cloth $19.95.

The title of this book only subtly alludes to some of the topics discussed. That is, many are daytime phenomena. Being introduced to sun pillars, sun dogs, double suns, the counter sun, and halo phenomena made me wonder if I have had blinders on all my life. And, although 100 rainbows (title of chapter 4) is a bit of an exaggeration in reference to the number of different bows that may actually be seen, the true number is indeed astonishing.

The excitement related by Fred Schaaf of looking out his window and seeing virtually all of the worlds in the solar system at once, as was possible near 12 February 1982 and near 13 January 1984 (and won't be again for a long long time), made me sad that I hadn't been more attentive to the occasions.

The author's campaign against light pollution is a worthy one, and results are indeed possible largely because there are cost benefits that can be advertised to developers, city planners, *et cetera.*

This book is largely a pep talk for sky watchers. If you have a casual (or greater) knowledge/interest in naked eye sky watching and want to get pumped up, then *The Starry Room* is for you.

—Jack Ames

BATTLING THE INLAND SEA: American Culture,
Public Policy, & the Sacramento Valley, 1850–1986
By Robert Kelley. 1989. University of California Press, Berkeley, CA, 416 p., $35.00

This book presents an excellent history of flood control efforts in the Sacramento valley primarily from the 1850's through 1920, when the present flood control system had been adopted and its implementation was well underway. Events from 1920 through the flood of 1986 are described briefly. The author describes the interrelationships between flood control, swampland reclamation and hydraulic mining. It is a story of repeated failures but eventually largely successful conclusion, as the largest flood of record was contained with minimal harm.

The author is a historian, and an important feature of the book is how he has interwoven flood control activities with the underlying social and political events. Among the latter is the evolution from a constitutional requirement that governmental actions be prescribed in detail in law to the acceptance of laws delegating considerable discretion to the executive branch to act within broad policy. Also of interest, is the shifts back and forth between populist driven local control and centralized professional management, depending primarily on whether the Democrats or Republicans controlled government.

In the Preface the author acknowledged that reclamation of the valley "ended in the destroying of a large natural environment". He, however, makes no attempt to describe the resources which were lost. Nevertheless, those interested in the evolution of our present society in the Sacramento valley will find the book worth reading.

—Harold K. Chadwick

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INSTRUCTIONS TO AUTHORS

EDITORIAL POLICY

California Fish and Game is a technical, professional, and educational journal devoted to the conservation and understanding of fish and wildlife. Original manuscripts submitted for consideration should deal with the California flora and fauna or provide information of direct interest and benefit to California researchers and managers. Authors should submit the original manuscript plus two copies, including tables and figures.

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3. *Abstracts*—Every article must be introduced by a concise abstract. Indent the abstract at each margin to identify it.

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